ENVIRONMENTAL IMPACT ASSESSMENT:

PROPOSED PEBBLE BED MODULAR REACTOR DEMONSTRATION POWER PLANT, AT THE KOEBERG NUCLEAR POWER STATION SITE

SURFACE WATER AND GROUNDWATER SPECIALIST ASSESSMENT

Report Prepared for

Eskom Holdings Limited

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January 2008

SRK Consulting
Engineers and Scientists

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Executive Summary

Groundwater

The Site is situated at the Koeberg Nuclear Power Station along the West Coast, approximately 30 km north of Cape Town CBD.

The Site is located some 4.5 km south of the Atlantis Water Resource Management Scheme that includes the Witzand and Silwerstroom Wellfields, Infiltration Ponds 7 and 12, and the Coastal Infiltration Ponds.

The Site overlies two aquifer systems, namely the southern extent of the upper primary or intergranular Atlantis Aquifer and the under-lying weathered and fractured-rock (secondary) aquifer system of the Malmesbury Group.

The thickness of the primary aquifer at the Site is ~ 13 m, as the rest groundwater level is some 7 mbgl and the overall thickness of the sediments is ~ 20 m.

Monitoring of groundwater levels indicates that levels at the Site vary between 3.4 and 4.3 mbgl. These shallow levels are the result of the groundwater at the Site being at the end of its flow path with the Site being very close to the coastline, i.e. located in a groundwater discharge zone.

Groundwater flows in a south-westerly direction towards the coast. Abstraction from production boreholes in the 'Aquarius Aquifer', even at high abstraction rates, will not impact on the Site.

Groundwater at the Site has a Na-Cl character, which is typical of groundwater in coastal zones. EC levels at the Site range between 270 and 305 mS/m, which is classified as marginal for drinking purposes and represents slightly saline conditions. The quality of the groundwater is a direct result of the closeness of these aquifers to the ocean.

Atlantis is largely dependent on groundwater for its water supply. Some 8.5 Mm^3/a of groundwater is abstracted from the primary aquifer systems (Witzand and Silwerstroom Wellfields). Groundwater is also used in the study area as a source of water to smallholdings and for brick making and sand mining. As the Site is located directly adjacent to the ocean, there is no groundwater use down-gradient of the Site.

Groundwater impact assessment matrices that have been prepared, show that the potential impacts at the Site are generally of low to medium consequence and thus has low to medium significance. The overall impact rating for groundwater is summarised in the table below.

Summary of overall rating for groundwater impacts

Criteria	Rating	
	Site-Specific	Off-Site (Air Emissions)
Extent or spatial influence of impact	LOW	REGIONAL
Intensity or magnitude of impact	LOW	HIGH
Duration of impact	SHORT-TERM to MEDIUM-TERM	LONG-TERM
Confidence	HIGH	HIGH
The activity will lead to an impact that is in all practical terms permanent	NO	YES

The groundwater specialist study confirms that there is no reason, from a groundwater perspective, why the planned PBMR DPP development at the existing Koeberg Nuclear Power Station should not be authorised. There are no fatal flaws in respect to the local Site groundwater dynamics, conditions and use.

Surface Water

No river channels drain the immediate Site. However, the perennial Salt and Diep Rivers drain the broader areas within the study area (10 km radius around the Site). The Donkergat River is a tributary of the Salt River.

Surface water impacts of the proposed project are largely related to the way in which local stormwater is managed. An integrated approach to stormwater management is encouraged, ensuring that water quality and quantity aspects are taken into account in the detailed design of stormwater management systems.

Surface water impact assessment matrices show the potential impacts to generally be of low consequence with the exception of impacts related to removing surface feeder water sources from wetlands, which carries a high consequence. Correspondingly, the significance ratings are generally low except for the wetland feeder cutoff impact, which is high. For all impacts, generally accepted best management practices can be employed as mitigation measures and should the mitigation measures suggested be implemented, all consequences (and corresponding significance rating) are reduced to low.

Recommendations

Groundwater

The objective of implementing mitigation measures and adhering to recommendations is to reduce potential impacts through the plant life cycle (construction to commissioning, to operation and ultimately decommissioning) of the planned PBMR DPP. Based on this, it is accepted that appropriate mitigation practises will form part of the design and planning through all phases of the proposed project.

To mitigate potential impacts during the various phases, a groundwater monitoring programme must be implemented. This is currently being initiated by SRK Consulting as part of a different project for Pebble Bed Modular Reactor (Pty) Ltd. It is intended to commence with the monitoring programme during December 2007 so that sufficient baseline groundwater level and quality data can be collected prior to construction.

Contamination of the soil and groundwater by accidental spills of fuel, oil and / or grease must be kept to a minimum by applying a good ‘housekeeping’ approach. In the event of any such spillages, procedures must be in place to quickly and effectively repair any leakages and remove the contaminated soil. This soil must be collected and disposed of at a suitably licensed waste disposal facility.

Continuation of the groundwater monitoring programme is essential, as it will provide:

- Information on groundwater quality down-gradient of specific source areas in order to obtain time series groundwater quality data of the selected constituents, to verify selection of management actions and to determine the effectiveness of those actions;
- A reference database from which remediation programmes can be developed, if required; and
- A legally defensible database against which any possible future claims against Eskom Holdings regarding environmental contamination or human health risk can be measured.

Surface Water

Implementation of the mitigation measures suggested is standard procedure and forms an integral part of best management practice in stormwater management design. It is recommended that all of these mitigation measures be implemented.

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Glossary

Anisotrophic: Having some physical property that varies with direction.

Aquifer: A geological formation, which has structures or textures that hold water or permit appreciable water movement through them [from the National Water Act (Act No. 36 of 1998)]. Also defined as the saturated zone of a geological formation beneath the water table, capable of supplying economic and usable volumes of groundwater to borehole(s) and / or springs.

Aquifer system: A heterogeneous body of interlayered permeable and less permeable material that acts as a water-yielding hydraulic unit covering a region.

Attenuation: The breakdown or dilution of contaminated water as it passes through the earth's material

Borehole: Includes a well, excavation, or any other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer [from the National Water Act (Act No. 36 of 1998)].

Catchment: The area from which any rainfall will drain into the watercourse, contributing to the runoff at a particular point in a river system, synonymous with the term river basin.

Contamination: The introduction of any substance into the environment by the action of man.

Design rainfall: That rainfall frequency/distribution/intensity that should influence civil design and stormwater management to take cognizance of both normal and extreme rainfall events.

Discharge area: An area in which subsurface water, including water in the unsaturated and saturated zones, is discharged at the land surface.

Ecosystem: An organic community of plants, animals and bacteria and the physical and chemical environment they inhabit.

Electrical conductivity: Is a measurement of the ease with which water conducts electricity. Distilled water conducts electricity poorly, while sea water, with its very high salt content, is a very good conductor of electricity.

Fault: A zone of displacement in rock formations resulting from forces of tension or compression in the earth's crust.

Formation: A general term used to describe a sequence of rock layers.

Fracture: Cracks, joints or breaks in the rock that can enhance water movement.

Geohydrology: The study of the properties, circulation and distribution of groundwater, in practise used interchangeably with hydrogeology; but in theory hydrogeology is the study of geology from the perspective of its role and influence in hydrology, while geohydrology is the study of hydrology from the perspective of the influence on geology.

Groundwater: Water found in the subsurface in the saturated zone below the water table or piezometric surface, i.e. the water table marks the upper surface of groundwater systems.

Groundwater flow: The movement of water through openings and pore spaces in rocks below the water table, i.e. in the saturated zone. Groundwater naturally drains from higher lying areas to low lying areas such as rivers, lakes and the oceans. The rate of flow depends on the slope of the water table and the transmissivity of the geological formations.

Groundwater resource: All groundwater available for beneficial use, including man, aquatic ecosystems and the greater environment.

Hydraulic conductivity: Measure of the ease with which water will pass through porous material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (in m/d).

Hydraulic gradient: Change in hydraulic head per unit of horizontal distance in a given direction, i.e. the difference in hydraulic head divided by the distance along the groundwater flow path. Groundwater flows from points of high elevation and pressure to points of low elevation and pressure.

Intergranular aquifer: Groundwater contained in intergranular interstices of sedimentary and weathered formations.

Leachate: Any liquid, including any suspended components in the liquid that has percolated through or drained from human-emplaced materials.

Lineaments: A major, linear, topographic feature of regional extent of structural or volcanic origin, most easily appreciated from remote sensing data, e.g. a fault system.

Major aquifer system: Highly permeable formations, usually with a known or probable presence of significant fracturing, may be highly productive and able to support large abstractions for public supply and other purposes, water quality is generally very good.

Non-aquifer system: Formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities, water quality may also be such that it renders the aquifer as unusable, groundwater flow through such rocks does take place and needs to be considered when assessing the risk associated with persistent contaminants.

Perched water table: Localised, unconfined groundwater separated from the underlying main body of groundwater by an unsaturated zone, i.e. the local water table is not in hydraulic continuity with the regional groundwater system.

Permeability: The ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time (expressed as $m^3/m^2/d$ or m/d); it is an intrinsic property of the porous medium and is independent of the properties of the saturating fluid; not to be confused with hydraulic conductivity which relates specifically to the movement of water.

Poor aquifer system: see non-aquifer system.

Recharge: The addition of water to the zone of saturation, either by the downward percolation of precipitation or surface water and / or the lateral migration of groundwater from adjacent aquifers.

Recharge area: An area over which recharge occurs.

Return period: Estimates of the likelihood of the occurrence of a given duration and intensity of precipitation, for analysis of the potential costs and benefits of building adequate controls. A return period is the frequency with which you would expect, *on average*, a given precipitation event to recur.

Runoff: All surface and subsurface flow from a catchment, but in practise refers to the flow in a river, i.e. excludes groundwater not discharged into a river.

Saline intrusion: Replacement of freshwater by saline water in an aquifer, usually as a result of groundwater abstraction.

Saline water: Water that is generally considered unsuitable for human consumption or for irrigation because of its high content of dissolved solids.

Saturated zone: The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.

Unsaturated zone: That part of the geological stratum above the water table where interstices and voids contain a combination of air and water; synonymous with the zone of aeration and vadose zone.

Vulnerable aquifer: May be contaminated or is easily susceptible to contamination from human and / or natural sources. A vulnerable aquifer is often not protected by overlying layers of soil serving to slow the rate of water movement from the ground surface. Improperly constructed or maintained boreholes can also increase the vulnerability of an aquifer by providing a direct route for contaminants to enter the aquifer.

Water Management Area: An area that is established as a management unit in the national water resource strategy within which a catchment management agency will conduct the protection, use, development, conservation, management and control of water resources [from the National Water Act (Act No. 36 of 1998)].

Water table: The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is at atmospheric pressure, the depth to which may fluctuate seasonally.

List of Abbreviations

CV:	Coefficient of Variation
DEA&DP:	Department of Environmental Affairs and Development Planning
DEAT:	Department of Environmental Affairs and Tourism
DTM:	Digital Terrain Model
DWAF:	Department of Water Affairs and Forestry
EC:	Electrical conductivity, measured as milliSiemens per meter (mS/m)
EIA:	Environmental Impact Assessment
GA:	General Authorisation
GEP:	Groundwater Exploitation Potential
GRP:	Groundwater Resource Potential
IWWMP:	Integrated Waste and Water Management Plan
K:	Hydraulic conductivity, measured as m/d
Ma:	Million years ago
mamsl:	metres above mean sea level
MAE:	Mean annual evaporation
MAP:	Mean annual precipitation
MAR:	Mean annual runoff
mbgl:	metres below ground level
NGDB:	National Groundwater Database
NWA:	National Water Act (Act No. 36 of 1998)
SRK:	SRK Consulting Engineers and Scientists (South Africa) (Pty) Ltd
T:	Transmissivity, measured as m^2/d
TMG:	Table Mountain Group

WMA: Water Management Area

WRC: Water Research Commission

WWTW: Wastewater treatment works

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Environmental Impact Assessment: Proposed Construction, Commissioning, Operation, Maintenance and Decommissioning of a Pebble Bed Modular Reactor Demonstration Power Plant, at the Koeberg Nuclear Power Station Site – Water Specialist Assessment

1 Introduction

It is proposed to construct, commission, operate, maintain and decommission a Pebble Bed Modular Reactor Demonstration Power Plant (PBMR DPP) with a nominal thermal output of 400 MW(t), at the existing, conventional, Koeberg Nuclear Power Station site (Figure 1).

Eskom Holdings Limited (Eskom) submitted an application during August 2005 for authorisation for the construction of the PBMR DPP to the Department of Environmental Affairs and Tourism (DEAT), in terms of Section 22 of the Environment Conservation Act, 1989 (Act 73 of 1989). Eskom subsequently appointed a consortium of environmental consultants, Mawatsan, to undertake the Environmental Impact Assessment (EIA) required for the PBMR DPP. This appointment was carried out in accordance with Regulation 3 (1) of Government Notice R.1183 (as amended), and promulgated in terms of Sections 26 and 28 of the Environment Conservation Act, 1989 (Act 73 of 1989). Mawatsan was contracted to fulfil the requirements of Regulations 5 and 6 of Government Notice R.1183 (as amended), namely the activities associated with the compilation of the Plan of Study for Scoping and Scoping Report.

Following the rejection of the Revised Final Environmental Scoping Report by DEAT, Eskom initiated a tender process for the completion of the EIA. The tender process resulted in ARCUS GIBB being appointed to fulfil the requirements of Regulations 7 and 8 of Government Notice R.1183 (as amended), namely the compilation of the Plan of Study for the EIA, the undertaking of the EIA, and the submission of the Environmental Impact Report.

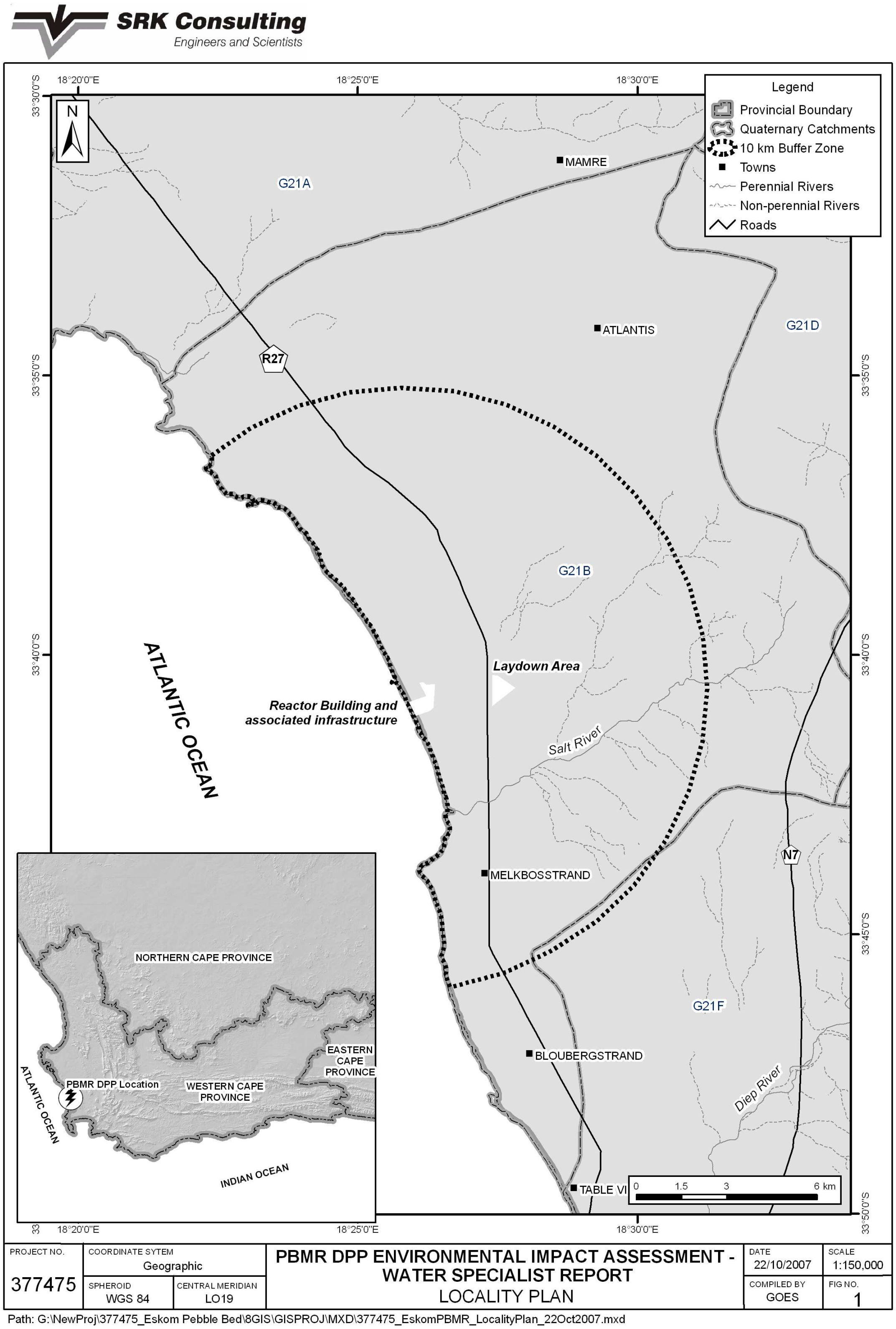

Figure 1: Locality Plan

A total of 24 specialist studies were identified as being required for the EIA process, including inter alia hydrology and hydrogeology. SRK Consulting has been appointed as the hydrogeological and hydrological specialists to undertake the water specialist assessment. This water specialist report forms part of the EIA process, and the report covers groundwater and surface water.

2 Terms of Reference

The purpose of this study is to assess the environmental impact on groundwater and surface water resources of the construction, commissioning, operation, maintenance and decommissioning of a PBMR DPP. This entailed the following:

- Design and undertake the specialist study in accordance with the specifications provided and with the specific objective of being able to provide a substantiated answer to the questions of relevance to this study;
- Undertake a gap analysis of the baseline data gathered during the EIA for the PBMR DPP and undertake the specialist study in such a way that the duplication of information is prevented;
- Describe the baseline conditions that exist at the Site and immediate surrounds and identify any sensitive areas that would require special consideration;
- Provide an outline of the approach used during the study including the level of confidence in the assessment undertaken;
- Include an assessment of the no-go alternative;
- Identify, assess and evaluate the possible impacts of the PBMR DPP during all development phases (construction, commissioning, operation, decommissioning) of the proposed project;
- In assessing the impacts of the operational phase, consideration must be given to:
    - Impacts during normal operation;
    - Impacts as a result of non-nuclear accidents and incidents; and
    - Impacts of a nuclear accident.
- Identify and assess any cumulative impacts arising from the proposed project;
- Determine the significance of the assessed impacts according to the methodology provided by ARCUS GIBB, and provide a revised significance rating of the assessed impacts after the implementation of mitigation measures;

- Identify areas where integration of studies with other specialists would ensure a more comprehensive assessment and coordinate with other specialists in this regard, especially freshwater consultants who are doing the specialist study on wetlands;

- Apply the precautionary principle in the assessment of impacts, in particular where there is significant uncertainty, low levels of confidence in predictions and poor data or information;

- Recommend practicable mitigation measures to minimise or eliminate negative impacts and / or enhance potential project benefits;

- Recommend appropriate auditing, monitoring and review measures;

- Compile all information into a stand-alone report according to the format provided by ARCUS GIBB; and

- Take cognisance of and comply with the relevant guideline documents applicable to the specialist study.

The scope of work for the groundwater assessment entailed the following:

- Describe the geological and hydrogeological characteristics of the study area in general;

- Identify sources of potable water in the region;

- Determine the potential for groundwater and surface water contamination;

- Identify vulnerable groundwater and surface water resources;

- Describe the pathways via which contamination could occur;

- Identify the possible extent of contamination should it occur; and

- Determine the effects of dewatering during construction.

The study is aimed at determining the impact of the life cycle activities and structures associated with the proposed PBMR DPP on the groundwater and surface water resources at the Site. Undertaking of field surveys was specifically excluded in the terms of reference for the water specialists study.

The Koeberg Site has been extensively investigated both prior to construction and since commissioning in the 1980's. Extensive investigations have also been carried out on the nearby Atlantis Aquifer and its surrounds since the mid-1970's. The confidence level in the conclusions drawn in this specialist study is therefore very high.

3 Planned PBMR DPP Development

3.1 Introduction

A brief description of the PBMR DPP is given in this section to give the reader some background knowledge of the proposed installation.

The PBMR is a nuclear energy technology that has a vertical steel reactor pressure vessel with a 6.2 m inner diameter and ~ 27 m length. The reactor pressure vessel contains and supports a metallic core barrel that contains pebble fuel spheres. The PBMR fuel consists of particles of low enriched uranium dioxide coated with silicon carbide and pyrolitic carbon. The particles are encased in a graphite sphere to form a fuel sphere or pebble about the size of a billiard ball. When fully loaded, the core would contain ~ 452 000 fuel spheres. The PBMR system is cooled with helium. The heat that is transferred by the helium to the power conversion system is converted into electricity through a turbine.

3.2 Building and Infrastructural Requirements

The estimated footprint of the proposed PBMR DPP site (the 'Site') post-construction is 9 ha (0.09 km^2). The construction and infrastructural requirements include:

- An integrated reactor building and generator building;
- A generator and associated electrical and auxiliary power plant;
- A services building;
- An ancillary building;
- A cooling water plant building;
- An administration office building;
- A 132 kV transmission power line between the Site and the Koeberg Substation;
- Widening a portion of the road to the Koeberg Nuclear Power Station from the R27 turnoff;
- Internal roads on the Koeberg Nuclear Power Station for access to the Site;
- Deviations on the road from Saldanha Harbour to the Site (around the Modder River bridge, the conveyor close to the Saldanha Harbour, as well as the existing 132 kV power line at Koeberg Nuclear Power Station);
- Contractor yard for the lay-down of materials and heavy equipment; and

- A village to house ~ 800 construction workers.

During construction the proposed PBMR DPP is no different from any other major construction project. Major activities such as site preparation, earthworks, civil works and mechanical installation will occur. Support activities such as material / equipment storage in a stock yard, and mechanical maintenance and servicing will also be performed (Mawatsan, 2007).

4 Study Approach

4.1 Delineation of the Study Area

The Site is situated at the Koeberg Nuclear Power Station along the West Coast, approximately 30 km north of Cape Town CBD. The Reactor Building and associated infrastructure is situated within the boundaries of the existing Nuclear Power Station, while the laydown area will be situated adjacent to the R27, directly east of the Power Station (Figure 1).

It is located within the municipal boundaries of the City of Cape Town and is situated on Cape Farm No. 34 Duynefontein, which is 1 257.39 ha in extent. Access to the Site is via the R27 (Provincial trunk road No.77). The recently authorised regional landfill site (Hazard rating H:h) and associated infrastructure to service the City of Cape Town will be established ~ 4 km north-east of the Site. The residential areas of Duynefontein and Melkbosstrand are located ~ 1 km and ~ 2.5 km, respectively, south of the Site, while the industrial and residential town of Atlantis is located ~ 10.5 km north-east of the Site.

The Site is also located some 4.5 km south of the Atlantis Water Resource Management Scheme (AWRMS) that includes the Witzand and Silwerstroom Wellfields, Infiltration Ponds 7 and 12, and the Coastal Infiltration Ponds. The Koeberg Nature Reserve, which was proclaimed as a nature reserve in 1991 and is composed of the Cape Floristic Kingdom, is located immediately north of the Site. The reserve consists predominantly of Strandveld and Acid Sand Plain Fynbos.

For the purpose of this study, a study area of 10 km radius around the Site has been defined to adequately cover quaternary catchments and aquifers.

4.2 Information Review / Desk Study and Gap Analysis

Extensive hydrogeological / hydrological investigations were carried out as part of the site investigation for Koeberg Nuclear Power Station in 1975, with follow-up groundwater level and quality monitoring. Further hydrogeological work was conducted at the site and its surrounds including investigations for additional local potable water supplies. These led to the development of a supply wellfield to the north-east of Koeberg. A Site Safety Report (SSR) has been produced covering all relevant aspects of hydrogeology and hydrology at the Site.

SRK Consulting reviewed the latter as part of the Phase 1 Nuclear Sites Investigation Programme during 2006 and subsequently produced detailed comments for Eskom.

Hydrogeological work was also carried out for the PBMR DPP during 2000 and 2001. A groundwater flow simulation model was developed to provide information on likely scenarios of water quality during dewatering for construction of the nuclear island foundations. A specialist water study was also carried out for the first EIA (Africon, 2001).

The desk study for this specialist assessment included a review of all available information. The information and data derived from previous work were combined with other reports and information of the area, including:

- DWAF's Groundwater Resource Assessment Phase 2 (GRA-II) project (i.e. quantification of groundwater storage, recharge, availability / exploitability of groundwater and groundwater use) (DWAF, 2005);
- Information and data obtained from a search of the National Groundwater Database (NGDB);
- DWAF and various consultants' reports;
- The DWAF 1:500 000 hydrogeological map of Cape Town;
- The DWAF aquifer classification map and related report;
- Knowledge of the local water situation gained during previous SRK Consulting investigations, e.g. at Atlantic Beach, Melkbosstrand Wastewater Treatment Works expansion and the Koeberg Nuclear Power Station potable water supply investigation; and
- Hydrogeological work by SRK Consulting (2007) as part of the EIA for Eskom Holdings Limited Generation Division, which entails the proposed construction and operation of a Conventional Nuclear Power Station and associated infrastructure in the Eastern, Northern or Western Cape areas.

The reference list is included as Section 11.

Based on the availability of information and data derived from these extensive hydrogeological / hydrological investigations at the site, the specialist study is not limited by any gaps and no further work is required.

4.3 Integration with Other Studies

SRK Consulting has been appointed to carry out both the surface and groundwater studies. Further, Freshwater Consulting has conducted the wetland ecological study. Comments and results from these studies were incorporated into this report.

4.4 Assumptions and Limitations

This specialist study report has been based on a desk study, as extensive, detailed hydrogeological and hydrological work has been carried out at and surrounding the Site (see Section 11). As a result of the availability of such detailed information and data, the specialist study was not limited in any way.

4.5 Defined Evaluation Criteria

This assessment of impacts was broadly carried out in accordance with the guidelines provided in the Guideline Document by CSIR (2005), and the NEMA principles and Section 24(4) of NEMA (as amended), as appropriate to this specific field of study.

The impact assessment methodology was based on a desktop review of existing information and no field work (e.g. exploration drilling) was undertaken / required (see Section 4.2).

5 Description of the Affected Environment

5.1 Physiographic Setting

5.1.1 Topography

The topography is relatively flat with a gentle slope towards the coast (Figure 2). However, both ancient dunes stabilised by vegetation and Recent unconsolidated dunes with heights < 10 m are found along the coastline.

5.1.2 Climate

The Site has a Mediterranean climate where summers are generally hot and dry while the winters are cold and wet. The average annual rainfall measured at the Koeberg Nuclear Power Station from 1980 to 2004 is 375 mm/a. Maximum rainfall occurs during June (~ 64 mm), July (~ 66 mm) and August (~ 53 mm), while the lowest rainfall occurs during January (~ 10 mm) and February (8 mm). Rainfall data pertinent to the Site was assessed for rainfall stations within 30 km of the Site. Data from the following stations was examined:

- Vanschoorsdrift, station number 0021130_W;
- Philadelphia Polisie, station number 0021130_A;
- Burgherspost, station number 0041060_W;
- De Grendel, station number 0021111_W;
- Cape Town Signal Hill, station number 0020715_W; and
- Table Mountain Tamboerskloof, station number 0020716_W.

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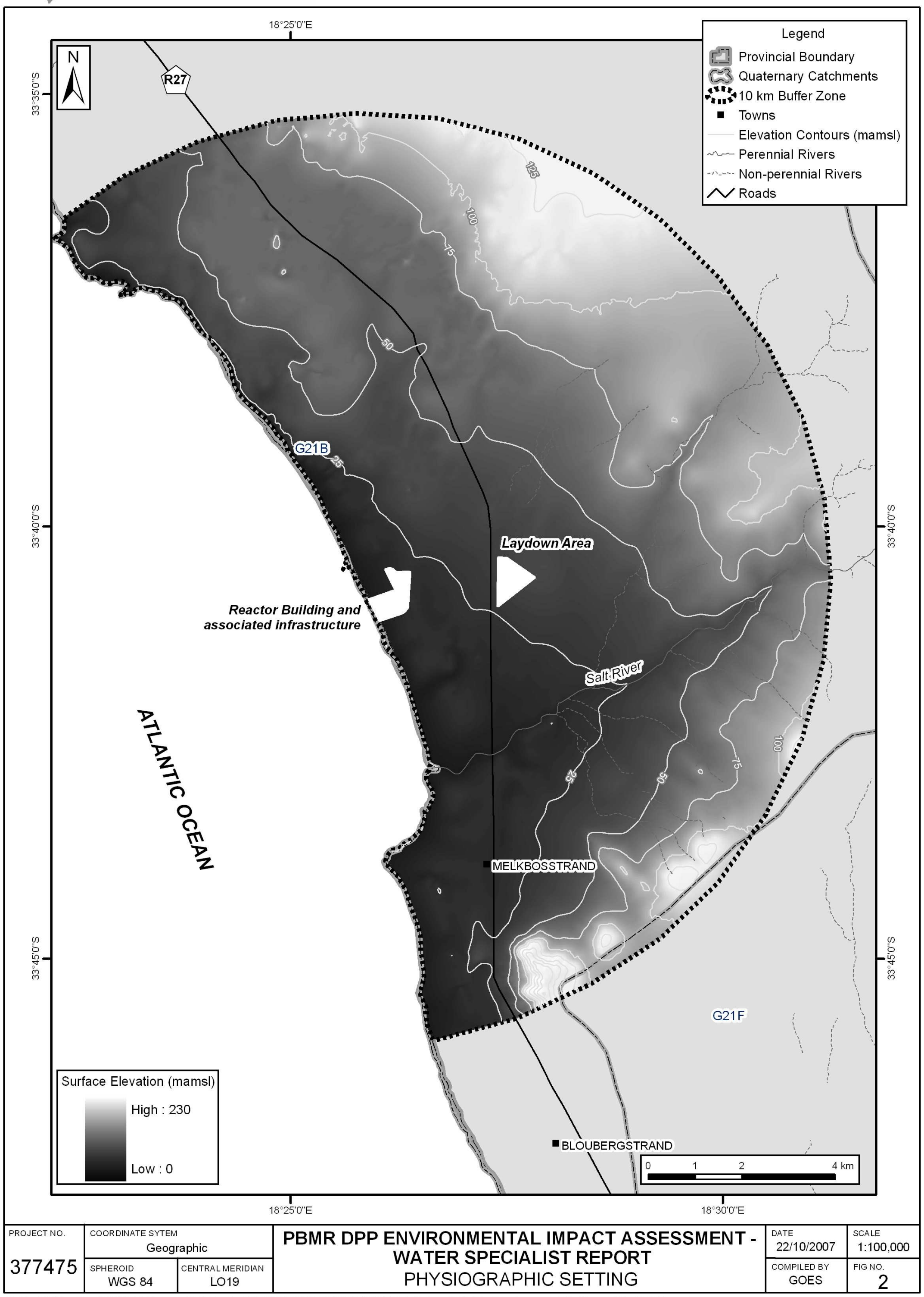

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Figure 2: Physiographic Setting

A summary of the likely design rainfall for the Site is given in Table 1.

These rainfall statistics correspond with the seasonal nature of rainfall in the area. The seasonal rainfall distribution measured from 1980 to 2006 at the Koeberg site is shown in Figure 3.

Figure 3: Rainfall Seasonal Distribution

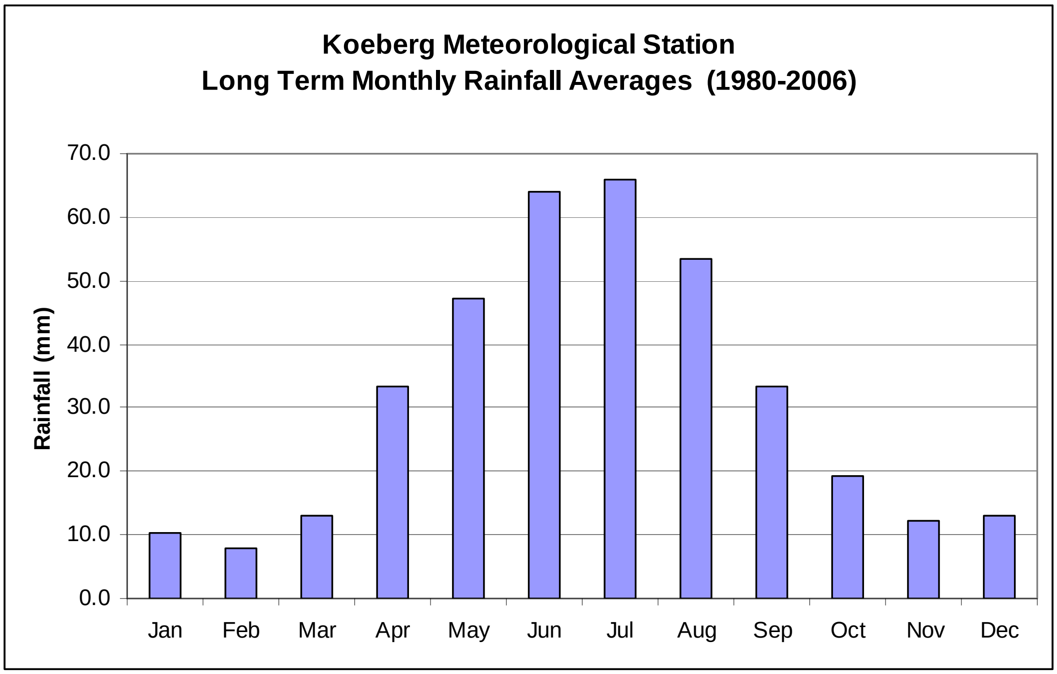


Table 1: Estimated design rainfall data

Duration	Return Period (Years)																	
(m/h/d)	2	2L	2U	5	5L	5U	10	10L	10U	20	20L	20U	50	50L	50U	100	100L	100U	200
5m	4.5	3.3	5.7	6	4.4	7.6	7.1	5.1	9.1	8.3	5.9	10.7	9.9	7	13	11.2	7.8	14.9	12.6
10m	6.4	5	7.8	8.6	6.7	10.5	10.1	7.8	12.5	11.8	9	14.6	14.1	10.6	17.7	16	11.9	20.4	18
15m	7.9	6.4	9.4	10.5	8.6	12.5	12.5	10	15	14.5	11.5	17.5	17.4	13.6	21.3	19.7	15.2	24.5	22.2
30m	10.2	7.9	12.5	13.6	10.5	16.7	16.2	12.4	19.9	18.8	14.2	23.4	22.5	16.8	28.4	25.5	18.8	32.7	28.7
45m	11.8	8.9	14.8	15.9	11.9	19.8	18.8	14	23.6	21.8	16.1	27.7	26.2	18.9	33.6	29.7	21.2	38.7	33.4
1h	13.2	9.7	16.7	17.6	13	22.3	20.9	15.2	26.6	24.3	17.5	31.2	29.1	20.7	37.9	33	23.1	43.6	37.2
1.5h	15.3	10.9	19.7	20.5	14.6	26.4	24.3	17.2	31.5	28.3	19.8	36.9	33.8	23.3	44.8	38.4	26.1	51.6	43.2
2h	17	11.9	22.2	22.8	16	29.8	27.1	18.8	35.5	31.5	21.6	41.6	37.7	25.4	50.5	42.7	28.5	58.2	48.1
4h	20.6	13.9	27.5	27.7	18.6	36.8	32.8	21.9	43.8	38.1	25.2	51.4	45.7	29.7	62.4	51.8	33.2	71.9	58.3
6h	23.1	15.2	31.1	31	20.4	41.6	36.7	24	49.6	42.7	27.6	58.1	51.1	32.5	70.6	58	36.4	81.3	65.3
8h	25	16.2	33.9	33.5	21.8	45.4	39.8	25.6	54.1	46.2	29.4	63.5	55.4	34.7	77.1	62.8	38.8	88.8	70.7
10h	26.6	17.1	36.3	35.7	22.9	48.6	42.3	26.9	58	49.2	30.9	67.9	58.9	36.5	82.5	66.8	40.8	95	75.3
12h	28	17.8	38.4	37.6	23.8	51.4	44.5	28	61.3	51.8	32.2	71.8	62	38	87.3	70.3	42.5	100.4	79.2
16h	30.3	19	41.9	40.7	25.4	56.1	48.2	29.9	66.9	56.1	34.3	78.4	67.1	40.5	95.2	76.1	45.3	109.6	85.8
20h	32.3	19.9	44.8	43.3	26.7	60	51.3	31.4	71.6	59.7	36.1	83.9	71.4	42.6	101.9	81	47.6	117.3	91.3
24h	33.9	20.8	47.4	45.5	27.8	63.5	54	32.7	75.7	62.8	37.6	88.7	75.1	44.3	107.8	85.2	49.6	124.1	96

Duration	Return Period (Years)																		
(m/h/d)	2	2L	2U	5	5L	5U	10	10L	10U	20	20L	20U	50	50L	50U	100	100L	100U	200
1d	29.2	17.8	40.8	39.1	23.9	54.6	46.4	28.1	65.1	54	32.3	76.2	64.6	38.1	92.7	73.2	42.6	106.6	82.5
2d	37	28.3	45.3	49.7	38	60.7	58.9	44.6	72.3	68.5	51.3	84.7	82	60.5	103	92.9	67.7	118.5	104.7
3d	42.6	37.1	48.2	57.1	49.7	64.5	67.7	58.4	76.9	78.7	67.1	90.1	94.2	79.2	109.5	106.8	88.6	126.1	120.4
4d	46.2	38.4	54	61.9	51.5	72.3	73.4	60.5	86.1	85.3	69.5	101	102.1	82	122.7	115.8	91.7	141.2	130.5
5d	49.1	39.4	58.9	65.9	52.9	78.9	78.1	62.1	94	90.9	71.4	110.2	108.7	84.2	133.9	123.3	94.2	154.2	139
6d	51.7	40.3	63.3	69.4	54.1	84.8	82.3	63.5	101	95.6	73	118.4	114.5	86.1	143.9	129.8	96.3	165.6	146.3
7d	54	41.1	67.2	72.4	55.1	90.1	85.9	64.7	107.4	99.9	74.3	125.8	119.5	87.7	152.9	135.6	98.1	176	152.8

L = lower percentile

U = upper percentile

5.2 Hydrology

5.2.1 Preamble

Because of the highly permeable nature of the sandy soils, no river channels drain the immediate Site. However, the Salt and Diep Rivers drain the broader areas within the study area (10 km radius around the Site) (Figure 2). These rivers all flow in a south-westerly direction towards the coast. Based on the nature of these rivers, Parsons and Flanagan (2006) suggested that groundwater does not discharge into the rivers. Most of the smaller streams ‘disappear’ in the flat sandy areas near the ocean and / or cannot maintain open river channels across the narrow raised dunes along the coast.

Water-logging occurs along limited areas after intense periods of precipitation. However, no flooding or stream flow occurs from adjacent properties (Africon, 2001). There are no dams or reservoirs present in the study area, and natural wetlands are prominent only during the rainy season. There are four identified wetlands north and south of the Site, which may indicate that groundwater levels are shallow in the area (see Section 5.3.6).

The Site falls within quaternary catchment G21B and in the Berg Water Management Area (WMA). Other catchments falling partly within the 10 km radius includes G21A and G21F (Table 2).

Table 2: Summary of quaternary catchment characteristics

Quat. Catch.	Gross Area (km^2)	Forest Area (km^2)	Irrig. Area (km^2)	Evap. Zone	MAE (mm/a)	Rain Zone	MAP (mm/a)	MAR (mm/a)	MAP-MAR RESP.	NET MAR (Mm^3/a)	GROSS MAR (Mm^3/a)	CV
G21A	523	252	0.0	23C	1 450	G1D	408	32	4	8.0	16.6	1.372
G21B	304	154	3.8	23C	1 445	G2A	424	32	4	4.9	9.6	1.267
G21F	242	221	5.4	23C	1 430	G2A	488	54	4	12.0	13.1	0.823

The high ‘coefficient of variation’ (CV) numbers indicates that the river channels in these catchments are generally non-perennial.

5.2.2 Storm Water Run-Off

Table 2 shows gross and net mean annual runoff (MAR) for primary watercourses draining nearby catchments.

Since the influence of these catchments and their watercourses on the project (and *vice versa*) will be negligible, it is necessary to investigate the local site catchments comprising the Project footprint to assess whether any significant impacts are expected.

The Project footprint comprises the Reactor Building and Associated Infrastructure on the Western side of the R27 as well as the proposed Contractor's Laydown Area on the Eastern side of the R27. Using the design rainfall data in Table 1, preliminary peak flows have been calculated using the Rational Method for each site. These calculated flows are shown in Table 3.

Table 3: Preliminary calculated peak flows

Return Period	Preliminary Calculated Peak Flows (m^3/s)	
	Laydown Area	Reactor Building Site
1:2	2.28	1.56
1:5	3.06	2.09
1:10	3.64	2.48
1:20	4.23	2.89
1:50	5.06	3.45
1:100	5.74	3.91
1:200	6.46	4.41

The peak flows presented in Table 3 are indicative of the stormwater runoff expected on the downstream side of each site. The calculations take the following assumptions into account:

- A stormwater cutoff berm is to be constructed on the upstream side of each site to prevent the sites from receiving stormwater from a wider catchment than their direct catchments;
- A primary stormwater management surface drain will be constructed along the main access roads on each site to receive stormwater from those areas proposed for development on each of the sites; and
- Conservative runoff coefficients have been assumed to present worst case scenarios.

5.2.3 Risks of Pollution

Pollution risks resulting from hydrological influences will be limited to plant design response to peak design rainfall and flows as indicated in Table 1 and Table 3. At the time of preparing this assessment, little to no detail was available on plant detailed design and thus the potential for waste streams to enter stormwater management systems is not fully understood.

As a conservative approach, preliminary calculations have been done to assess how much water would need to be retained on each site should an assumption be made that all runoff from plant areas could be contaminated and could require treatment in a retention facility. The potential retention volumes and dimensions of hypothetical retention facilities should plant runoff require retention, is indicated in Table 4. The retention facility footprint assumes that a maximum depth of 3.5 m in the facility is attainable, this depth influenced by the depth to groundwater (on average ~ 4 m below natural ground level) and the need for 0.5 m freeboard.

Table 4: Preliminary estimates of retention facility capacity requirements

Site	Preliminary Calculated Storm Volumes (m^3)					
	1:2	1:5	1:10	1:20	1:50	1:100
Contractor's Laydown	2 696	3 797	4 534	5 365	6 568	7 465
PBMR DPP	2 029	2 858	3 412	4 038	4 944	5 641
	Preliminary Calculated Retention Facility Footprint Area (m^2)					
Contractor's Laydown	771	1085	1296	1533	1877	2133
PBMR DPP	580	817	975	1154	1413	1612

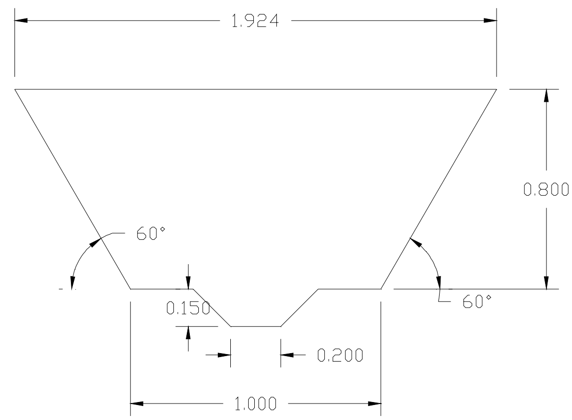
It can be seen that, to contain the 1:50 year flood runoff from each Site, requires a 3.5 m deep retention pond measuring between ~1 900 m^2 and ~1 400 m^2 (a facility measuring ~40m X 40m). This forms a small percentage of the area proposed for development on each Site.

5.2.4 Watercourse Hydraulics and Floodline Determination

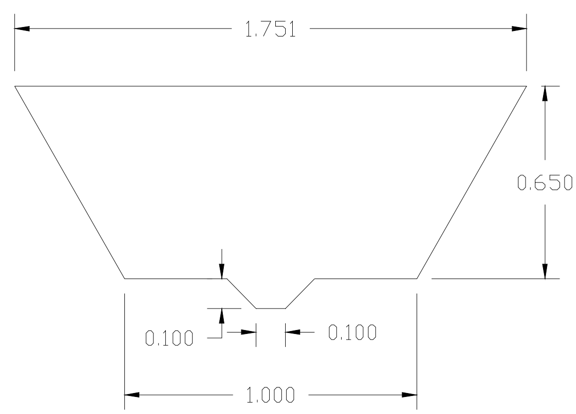
Floodlines and flood levels on natural watercourses will not play a significant role in the Site sensitivity analysis with the Salt River flowing some 5 km south of the Site.

Flood hydraulics must, however, take cognisance of plant stormwater management needs. Extrapolating on the assumption in Section 5.2.2 that a primary surface drain will follow the main access road on each site, primary surface drains have been sized for each site based on the peak flows in Table 3. The expected dimensions of these drains are shown in Figure 4.

Figure 4: Preliminary Primary Surface Drain Dimensions



(a) Laydown Area Site (Dimensions in m)



(b) Reactor Building Site (Dimensions in m)

It is a feature of industrial site stormwater management that surface drains are often maintenance intensive particularly in the need to extract silt from drains. On the sites in question, flat gradients are a feature and stormwater conduits will be constructed with similar gradients. Silt build up in channels is highly likely and it is probable that a 'low flow' channel will be required as shown in Figure 4 to mitigate against silt build up during base flow conditions.

5.2.5 Site Specific Stormwater Management

As shown in the preceding sections, it is probable that site stormwater management could become an important plant design parameter. Integrating stormwater quantity and quality into design is encouraged based on the following observations:

- The proposed development is industrial and could generate contaminated runoff;

- It may be necessary to retain a portion of this runoff on site, potentially treat it and then release it;

- Retention volumes could result in the need to construct retention facilities covering areas no greater than 2 000m^2;

- The local Site catchment characteristics and local rainfall patterns are expected to generate peak flows that will demand an engineered stormwater management infrastructure; and

- The preliminary peak flows calculated are reasonably high even when assuming that surface water from upstream of the Sites is arrested at the Site boundaries. It therefore stands to reason that it may be necessary to create upstream stormwater cutoff berms to limit additional stormwater flowing onto the sites, additional water that will add to the flows in Table 3.

With this in mind, it is likely that detailed design will require an integrated stormwater management approach in which primary forms of contamination containment (e.g. drip trays and bunding containment areas) feature. The motivation for this would be to reduce the potential runoff volumes of contaminated rain water and thus reduce the need for contaminated rainwater runoff retention and treatment. Isolating contaminated stormwater will also allow the natural flow of rain water into wetland systems from catchments within the Sites.

5.2.6 Dam Break Modelling

No dam break modelling is required for this Site as dam failure in the region will not pose any risks to the Site.

5.3 Geology

The general geology of the coastal sediments of the Site has been described by Rogers (1980), Fleisher (1990), Parsons (1991), Wright (1991), Cavé (1997) and Parsons (2002). The study area is situated on very old [Neoproterozoic (835 - 720 Ma)] rocks of the Malmesbury Group, intruded by the late Neoproterozoic Cape Granite Suite and Cretaceous (145 - 65 Ma) dolerite dykes, and overlain by Cenozoic (65.5 Ma to present) unconsolidated material (Figure 5).

5.3.1 Unconsolidated Sediments

The superficial, unconsolidated sediments comprise the Bredasdorp Group (Varswater, Springfontein and Langebaan Formations) and Recent Witzand Formation, which forms the Atlantis Aquifer. The Springfontein Formation acts as the main water-bearing formation and comprises well-sorted, clean fine to medium grained quartz sand. The sediments were deposited under marine, fluvial and / or aeolian conditions. Sand thickness increases closer towards the coast.

The results of previous drilling at the Site indicated a profile consisting of 3 to 4.5 m of slightly calcareous sand at the top becoming organic rich with shell fragments below 7.5 m (Dames and Moore, 1975a; 1975b; 1977c). The lower parts also consist of pebbly sand grading down into gravels. The thickness of the unconsolidated sediments at the Site is ~ 20 m, while further east of the Site it increases to ~ 50 m (Fleisher, 1993; Rosewarne, 1994; Jones and Wagener, 2000).

5.3.2 Sedimentary Rocks

The areas east and further inland of the Site has outcrops of the Tygerberg Formation of the Malmesbury Group, and comprises phyllitic shale and impure sandstones (greywacke) that weather to produce substantial thickness of yellow and / or grey clay. These consolidated sedimentary rocks underlie the entire study area and form the semi-impervious base of the Atlantis Aquifer. At the Site, alternating successions of greywacke, siltstone and mudstone have been identified, with the beds dipping some 60° to the west (Greef, 1995). These consolidated sediments are highly weathered along the upper 10 m, with some 3.7 m of residual clayey silt being observed during previous drilling programmes at the Site (Jones and Wagener, 2000).

5.3.3 Intrusive Rocks

The Malmesbury Group rocks have been extensively intruded by the Cape Granite Suite. As the coarse-grained granite of the Darling Pluton outcrops some 15 km away from the Site towards the north-eastern portion of the study area, these granitic rocks are not discussed further.

5.3.4 Structural Geology

The regional Saldanha-Darling-Franschhoek Fault Zone lies some 30 km east of the Site and is thus outside of the study area and poses no threat to activities at the Site (Eskom, 2006a) (Figure 5). According to Eskom (2006c), no evidence exist that the postulated Cape Hangklip-Milnerton Fault Zone approaches closer than 8 km to the Site.

Based on previous excavations at the Duynefontein Site, it is known that the Malmesbury Group rocks are extensively faulted and fractured. Extensive minor geological lineations with a NNW strike exist in the vicinity of the Site. This was revealed by geological mapping and a regional aeromagnetic investigation carried out in 1975, and verified during 1999 when airborne magnetic and gamma-ray spectrometric investigations were conducted by the Council of Geoscience. Opportunely, the present-day stress field generated along the mid-Atlantis Ridge is at ~ 90° angles to these minor faults and this stress field is larger than the stress field generated at the southern African plate margin. The former stress field is also sub-horizontal and therefore ‘locks’ the faults into position and negates movement along these faults. Hence, although minor faults occur in the vicinity of the Site, such faults should not impact on activities there.

According to Africon (2001), fracture zones in the bedrock are infilled by secondary quartz to form a honeycomb structure, which has a degree of porosity and hydraulic conductivity from which good supplies of water may be obtained.

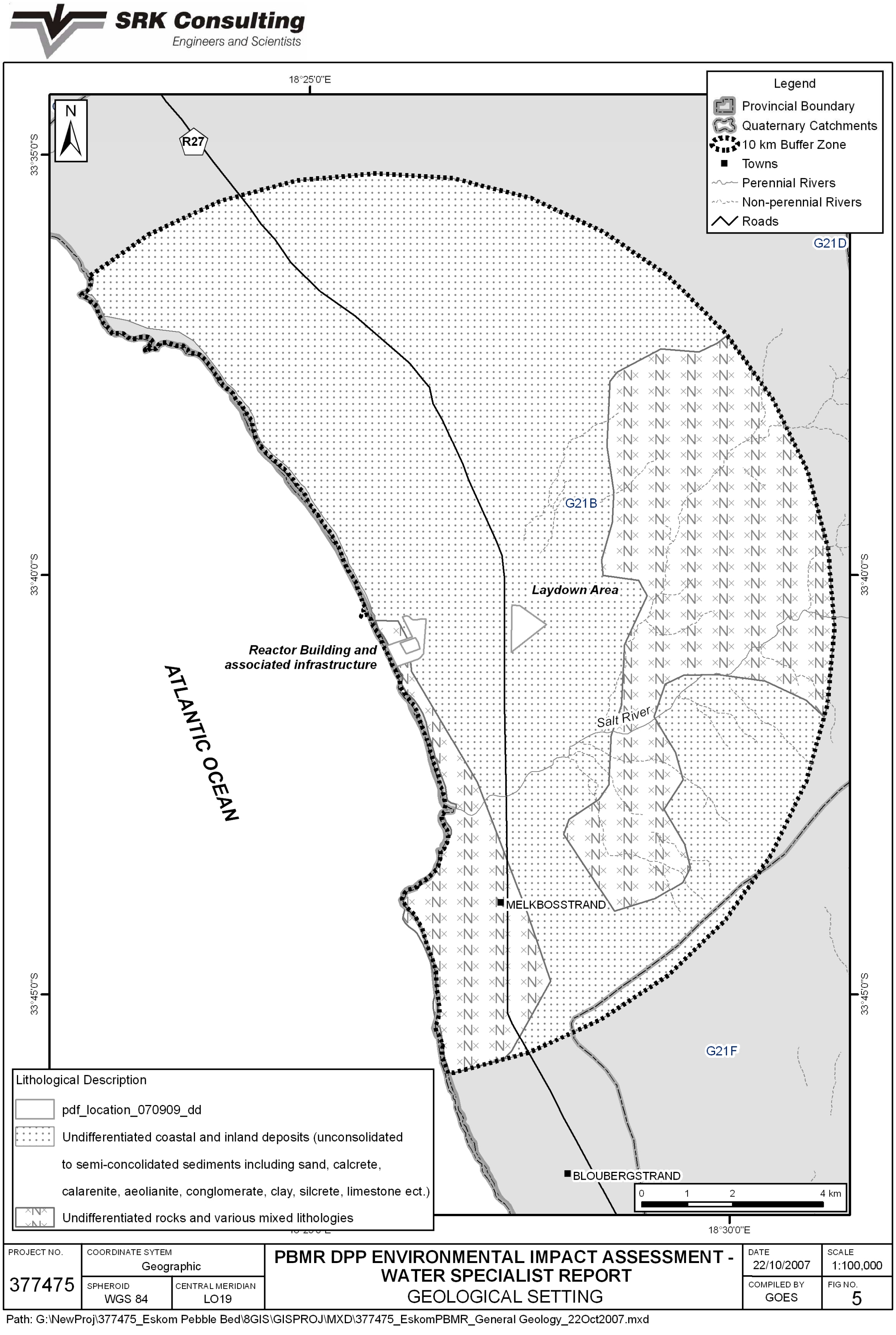


Figure 5: Geological Setting

5.4 Hydrogeology

At a coastal nuclear site such as Koeberg, the nuclear footprint is located very close to the coastline. In terms of the hydrological / groundwater cycle, this means that it is located in a groundwater discharge zone. There are therefore certain hydrogeological characteristics that are likely to be common to such sites and that must be taken into consideration in the EIA. These are:

- There will not be any downstream groundwater use;
- Groundwater at the Site will be near/at the end of its flow path;
- There will be a component of groundwater flow towards the water table (i.e. upwards);
- Groundwater levels will be near the ground surface;
- The bedrock may comprise a wave-cut platform;
- The receiving environment / downstream receptor of any contamination will be the shore zone / sea;
- There is likely to be a two aquifer system at the Site, with an upper intergranular and a lower fractured rock aquifer;
- These aquifers are likely to be in hydraulic connection but may be separated by a weathered zone in the bedrock possibly constituting an aquitard;
- Local recharge may only affect the upper aquifer. Deeper aquifers may be recharged inland, possibly many kilometres from the Site;
- Groundwater quality may be relatively poor because of a combination of length of the flow path, time for interaction with aquifer materials and proximity to the sea (sea-water intrusion, wind blown salts);
- Groundwater flow rates are likely to be relatively slow because of low hydraulic gradients;
- There will be an interface between ‘fresh’ groundwater from inland and saline groundwater in the shore-zone;
- Groundwater may feed coastal springs / seeps which may support sensitive ecosystems; and
- Leaks of radioactivity will not affect existing groundwater users directly. However, air emissions could be transported inland by prevailing winds and contaminate the groundwater by being incorporated into rainfall recharge.

5.4.1 Aquifer Types

The Site overlies two aquifer systems, namely the southern extent of the upper-lying primary or intergranular Atlantis Aquifer and the deeper-lying weathered and fractured-rock (secondary) aquifer system of the Malmesbury Group (Figure 6). The thickness of the primary aquifer at the Site is ~ 13 m, as the rest groundwater level is some 7 m below ground level (mbgl) and the overall thickness of the sediments is ~ 20 m.

The secondary aquifer is a semi-confined system which is in hydraulic connection with the overlying primary aquifer. Interpretation of pumping test results supports the hypothesis that upward leakage from the Malmesbury Group Aquifer to the primary aquifer can be expected once the water table in the sands is drawn-down below the piezometric level in the underlying semi-confined aquifer (Murray and Saayman, 2000). These two aquifer systems are separated by a weathered zone in the bedrock, which may constitute an aquitard.

The Atlantis Aquifer is an important and significant primary aquifer with two wellfields (Witzand and Silwerstroom) situated north of the Site supplying water to the surrounding towns, predominantly to Atlantis.

5.4.2 Hydraulic Properties

Primary Aquifer

Pumping tests and double-ring infiltrometer tests have previously been conducted in the Atlantis Aquifer by Van der Merwe (1980), Bredenkamp and Vandoolaeghe (1982), Scott (1989) and Weaver (1989). Transmissivity (T) values determined from these tests ranged between 10 and 1 400 m^2/d. From these data, hydraulic conductivity (K) for the various formations of the Atlantis Aquifer were found to range between 13 and 35 m/d, with the exception of the Varswater Formation (1 to 3.5 m/d).

At the Site itself, T values of the primary aquifer were estimated to be ~ 40 m^2/d (Dames and Moore, 1980; Murray and Saayman, 2000). This value represents the upper 15 m of the aquifer, and does not reflect conditions of the finer sands at the base of the aquifer (Murray and Saayman, 2000). The average K at the Site was found to be ~ 2.6 m/d (Murray and Saayman, 2000), with the more permeable, upper layers of the primary aquifer ranging between 3 and 10.4 m/d, and the underlying, less permeable layers ranging between 0.004 and 0.005 m/d. Murray and Saayman (2000) determined the Storativity (S) to be 0.04, or 4 %.

Secondary Aquifer

Parsons and Flanagan (2006) found that K values for the secondary, fractured aquifer indicated these aquifers to be poorly transmissive, with K ranging between 0.01 and 0.06 m/d. Where the shale is less weathered, K values increase to approximately 0.2 m/d. The S value for the secondary aquifer was determined to be 0.006 by Dames and Moore (1980) and between 0.0001 and 0.004 by Murray and Saayman (2000).

Based on the results of pumping tests undertaken by Dames and Moore (1980) in the area north-east of the foundation of the existing power plant, a T value of 0.2 m^2/d for the Malmesbury Group

Aquifer was determined. However, the secondary aquifer is highly anisotropic, and aquifer parameters vary significantly across the aquifer. This has been confirmed by work done by Murray and Saayman (2000), whereby the T value at borehole P-01 was determined to be 30 m^2/d.

5.4.3 Borehole Yields

Yields of > 10 L/s are obtained from production boreholes in the Witzand and Silwerstroom Wellfields north of the Site. Boreholes drilled into sands along the north-eastern parts of the study area were reported to yield in excess of 5 L/s (Parsons, 2002) (Figure 6). However, boreholes drilled into the Malmesbury Group Aquifer yield considerably less, i.e. < 2 L/s. This is consistent with the findings of Meyer (2001) in his assessment of the Malmesbury Group Aquifer. Exploration boreholes drilled in the shale at the regional landfill site yielded between 0.1 and 0.3 L/s (Parsons and Flanagan, 2006). During exploratory drilling at the Site carried out by Saayman and Weaver (2001), a fracture yielding in excess of 12 L/s was encountered, but pumping at this rate would not be feasible due to the increased potential for saline intrusion.

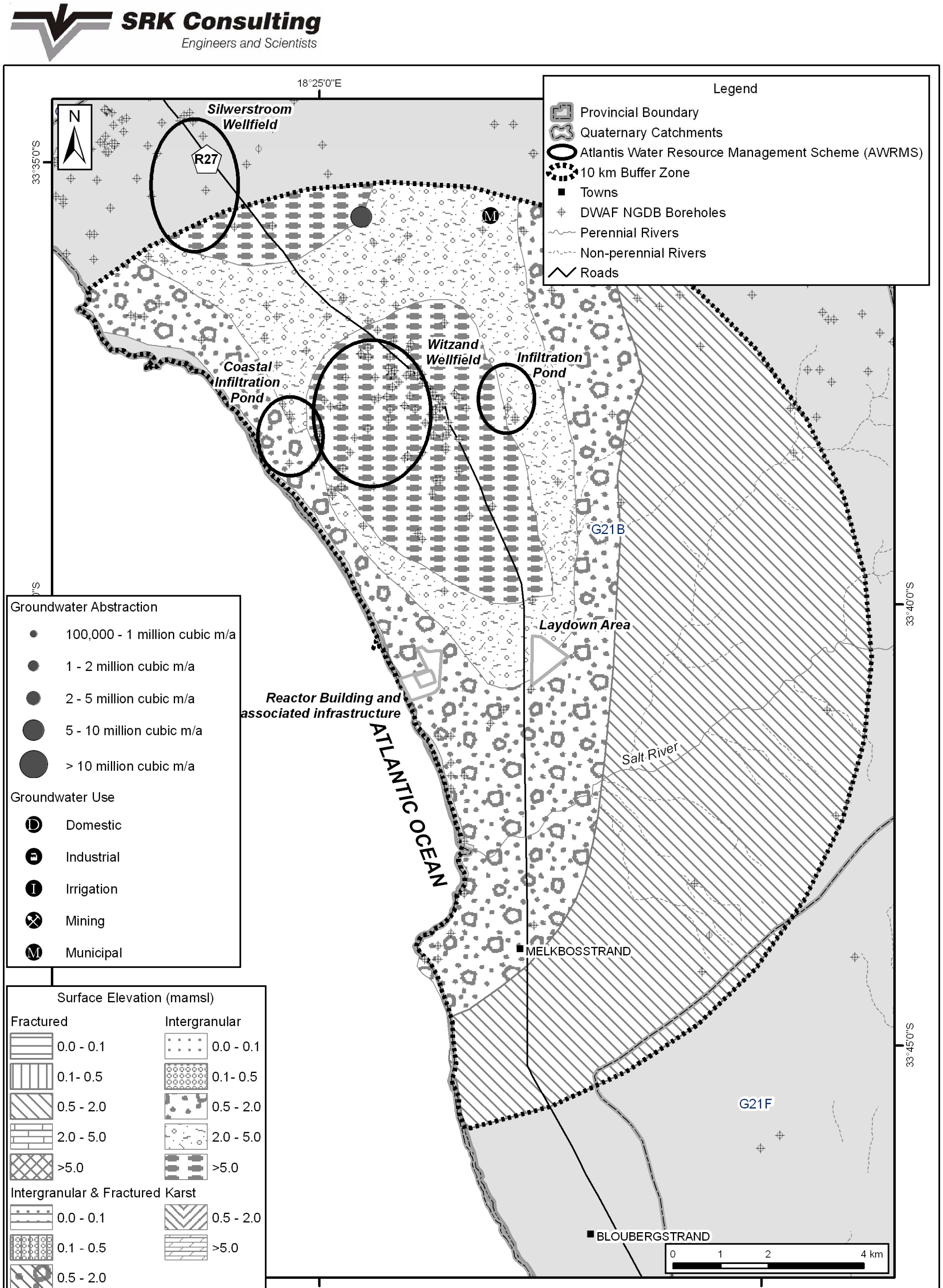
Saayman and Weaver (2001) reported that previous aquifer tests conducted on boreholes drilled into the primary aquifer showed a stabilisation of groundwater level drawdown at sea level or just above, when pumping such boreholes at ~ 2.5 L/s. The construction dewatering programme will have to take this rate of groundwater abstraction into consideration.

5.4.4 Recharge

Estimates of recharge (as a percentage of rainfall) in the study area have been presented by Bredenkamp and Vandoolaeghe (1982), Vandoolaeghe and Bertram (1982), Bertram *et al.* (1983), Fleisher (1990), Fleisher and Eskes (1992) and others. Average recharge was estimated to be between 10 and 30 % of MAP, with Fleisher (1990) suggesting it to be 16 % of MAP. Due to the unconfined nature of the upper sediments, recharge takes place over the entire area.

Africon (2001) analysed for tritium (^3H) to determine areas of recharge. An interpretation of the results showed that the groundwater regime is less dynamic in the lower lying secondary aquifer than in the primary aquifer, which indicates that negligible or no recharge to the former aquifer occurs in the study area. Significant ^3H concentrations [> 1 tritium units (TU)] in the primary aquifer indicate a fairly dynamic system with groundwater in the aquifer being some 10 to 20 years old.

Local recharge therefore only affects the primary aquifer, while the deeper aquifer is recharged further inland, possibly several kilometres east of the Site (as previously postulated).



PROJECT NO.	COORDINATE SYTEM		PBMR DPP ENVIRONMENTAL IMPACT ASSESSMENT - WATER SPECIALIST REPORT	DATE	SCALE
377475	Geographic		AQUIFER TYPES	22/10/2007	1:100,000
	SPHEROID	CENTRAL MERIDIAN		COMPILED BY	FIG NO.
	WGS 84	LO19		GOES	6

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Figure 6: Aquifer Types (DWAF 1:500 000 Hydrogeological Map Series)

5.4.5 Groundwater Levels

Depth to groundwater is important, primarily because it determines the depth of material through which any contaminants must migrate before reaching an aquifer. There is a greater chance for attenuation of contaminants to occur as the depth to groundwater increases, and aquifer vulnerability decreases.

Measurement of groundwater levels by Murray and Saayman (2000) indicates that levels at the Site vary between 3.4 and 4.3 m below ground level (mbgl). These shallow levels are the result of the groundwater at the Site being at the end of its flow path with the Site being very close to the coastline, i.e. located in a groundwater discharge zone. The deeper groundwater levels occur along the north-eastern portion of the Site (~ 4.3 mbgl), while shallower levels were measured towards the south-west (~ 3.4 mbgl). Groundwater levels measured in the deeper boreholes (i.e. secondary aquifer) and that measured in the shallow boreholes (i.e. primary aquifer) vary by < 0.5 m (Murray and Saayman, 2000). This supports the contention that the Malmesbury Group Aquifer is a semi-confined system (see Section 5.4.1).

According to Dames and Moore (1980), seasonal rainfall variation does not significantly affect the groundwater flow direction or groundwater levels at the Site. The influence of tides may impact on temporal variations in groundwater levels. Based on observations by Dames and Moore (1975a; 1975b), groundwater levels west of the Koeberg 900 MW PWR Units 1 and 2 fluctuated by some 0.55 m during construction of the units, and by 0.7 m within the foundation area of the units.

5.4.6 Direction of Groundwater Flow

A regional groundwater level contour map was compiled by Parsons and Flanagan (2006) using data collected from ongoing monitoring carried out by the CSIR and that collected during a hydrocensus conducted during August and September 2004. From this, it was interpreted that groundwater flows in a south-westerly direction towards the coast (Figure 7). Using the data collected by Murray and Saayman (2000), a detailed Site groundwater level contour map was compiled (see insert in Figure 7).

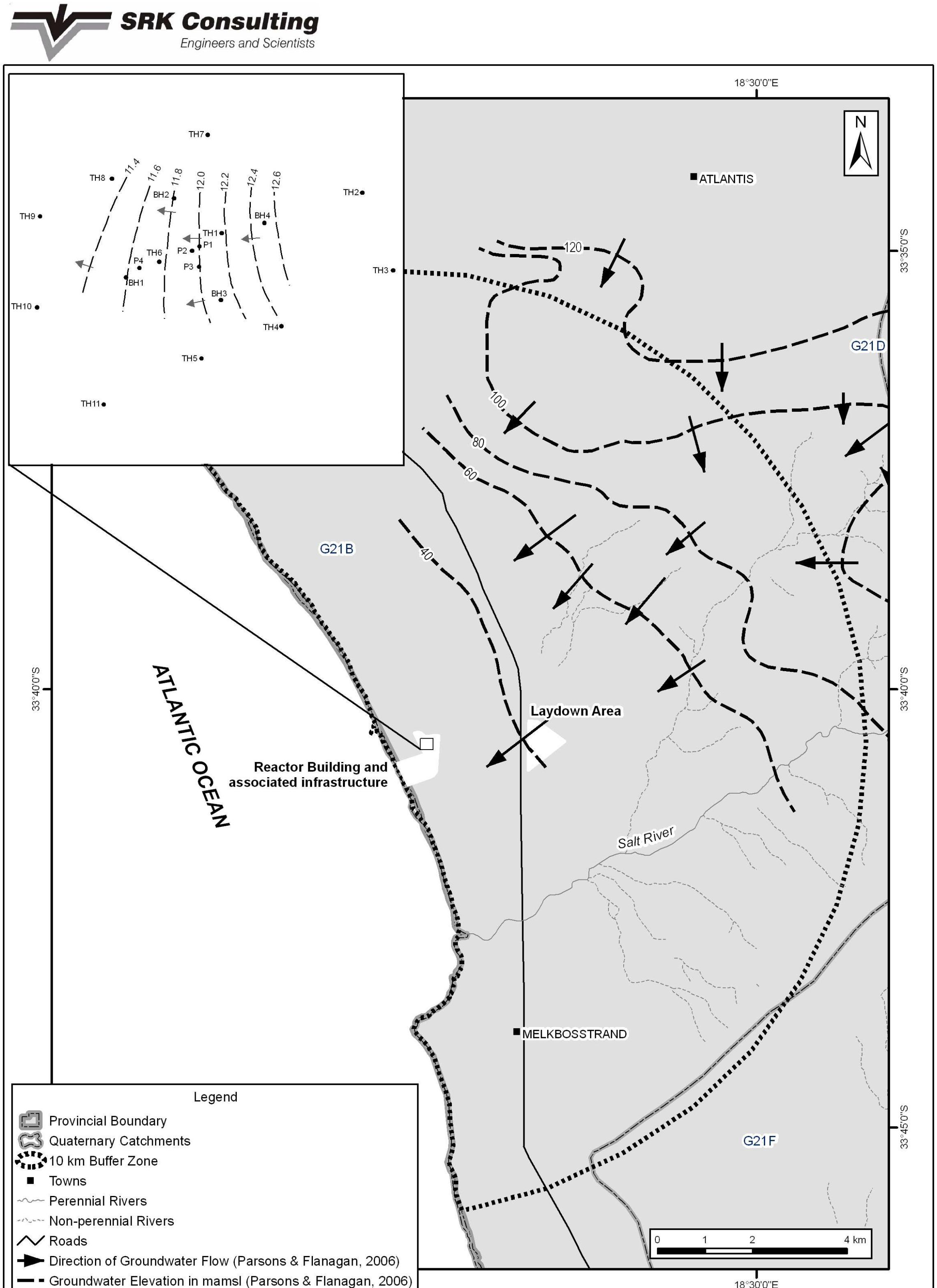
As the Site is located very close to the coastline, in terms of the hydrological / groundwater cycle the Site is located in a groundwater discharge zone. Groundwater at the Site is at the end of its flow path.

Numerical modelling has been carried out in the Atlantis and Witzands area by the CSIR to establish the impact of groundwater abstraction on regional flow patterns. The impact of abstraction from the Koeberg Nuclear Power Station production boreholes, drilled into the 'Aquarius Aquifer', has also been simulated by the CSIR (Du Toit *et al.*, 1995). According to these models, even at high abstraction rates, the resulting maximum cone of depression (drawdown contours) will not reach the Site. Groundwater flow will only be reversed due to over-abstraction at the wellfields up-gradient of the Site. Based on information derived from the models, it is not likely that contamination occurring at the Site can impact on the major aquifer systems up-gradient. The receiving environment / downstream receptor of any contamination will be the shore zone / ocean. This excludes air emissions, which are discussed under Section 5.4.9.

5.4.7 Hydraulic Gradient and Rate of Groundwater Flow

The hydraulic gradient across the Site is 0.014 (Africon, 2000). Further north-east of the Site, Parsons and Flanagan (2006) determined the hydraulic gradient to be 0.011.

Murray and Saayman (2000) calculated that groundwater flows towards the coast at a rate of ~ 2.6 m/d, which indicates a relatively quick migration across the Site. The rate of flow through the Malmesbury Group Aquifer was estimated by Parsons and Flanagan (2006) to be 1 m/a (0.003 m/d). This slow groundwater flow rate is a result of the low hydraulic gradient.



PROJECT NO.	COORDINATE SYTEM		PBMR DPP ENVIRONMENTAL IMPACT ASSESSMENT - WATER SPECIALIST REPORT	DATE	SCALE
377475	Geographic			22/10/2007	1:100,000
	SPHEROID	CENTRAL MERIDIAN	INTERPRETED DIRECTION OF REGIONAL GROUNDWATER FLOW	COMPILED BY	FIG NO.
	WGS 84	LO19		GOES	7

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Figure 7: Interpreted Direction of Regional Groundwater Flow Direction (after Parsons and Flanagan, 2006)

5.4.8 Groundwater Use

Atlantis is largely dependent on groundwater for its water supply. Based on Parsons' (1999) estimated groundwater usage figures, about 8.5 Mm^3/a of groundwater is abstracted from the primary aquifer systems (Witzand and Silwerstroom Wellfields) (Figure 6). Groundwater is also used in the study area as a source of water to smallholdings and for brick making and sand mining (Parsons and Flanagan, 2006). Groundwater is predominantly used for small-scale vegetable farming, water for horses and irrigation of commercial (instant) lawn. Twelve boreholes were initially drilled in the Aquarius Wellfield to supply process water at the Koeberg Nuclear Power Station, but they have not been used during the past few years due to high EC levels (Parsons and Flanagan, 2006).

Reticulated municipal water is available to most smallholdings in the study area from a pipeline constructed during 2002, but is only used to a limited extent by the smallholdings because of the relatively high cost thereof. Groundwater is still the preferred choice for water supply (Parsons and Flanagan, 2006).

According to Africon (2001), there are a number of wellpoints at Koeberg Nuclear Power Station and Duinefontein, which are used for garden irrigation.

5.4.9 Groundwater Quality

Regional groundwater quality of the Atlantis Aquifer was discussed in detail by Fleisher (1990). Vandoolaeghe and Bertram (1982) classified the groundwater of this aquifer as Class A type [electrical conductivity (EC) $<$ 70 mS/m]. The groundwater is generally a sodium (Na) - chloride (Cl) type, but younger groundwater in the study area tends towards a calcium (Ca) – bicarbonate (HCO_3) character (Parsons, 1999) (Figure 8).

Interpretation of groundwater quality data collected at boreholes P-01, P-02 and P-04 confirms that groundwater quality at the Site has a Na-Cl character, which is typical of groundwater in coastal environments (Figure 9). EC levels at the Site range between 270 and 305 mS/m. According to the DWAF (1998), *Quality Guidelines for Domestic Water Supplies*, this range is classified as marginal for drinking purposes and represents slightly saline conditions. The quality of this groundwater is a direct result of the closeness of these aquifers to the ocean, i.e. at the end of the flow path and influence of frontal rainfall recharge and sea-spray / aerosols.

Saayman and Weaver (2001) showed that groundwater derived from the primary aquifer underlying the Site and that from the Malmesbury Group Aquifer were of a similar quality. The similarity in quality supports the hypothesis that the two aquifer systems are hydraulically connected.

Although EC levels and Na and Cl concentrations are similar, the average iron (Fe) concentration in the secondary aquifer is greater at 3.7 mg/L (as compared to ~ 0.3 mg/L in groundwater in the primary aquifer) (Saayman and Weaver, 2001).

Four exploration boreholes were drilled at the planned Koeberg 165 MW PBMR Unit 3 site and baseline groundwater quality data has been obtained (Africon, 2001). Tritium data indicated that groundwater in the Malmesbury Group Aquifer is saline and not recharged locally, which indicates stratification in age and quality between the primary sediments and the secondary aquifer. Future pumping and dewatering may disturb this stratification and inflow of saline groundwater into the upper primary aquifer may occur.

Africon (2001) analysed for stable environmental isotopes deuterium (δD) and oxygen-18 ($\delta^{18}O$). These analyses were undertaken to determine the origin and age of groundwater at the Site, provide an estimate of the degree of mixing of groundwater in the primary and secondary aquifers and indicate the rate of groundwater flow. Based on the results presented by Africon (2001), $\delta^{18}O$ concentrations in the adjacent dune areas (the higher lying areas) represent ‘young’, recently recharged groundwater, whereas along the lower lying areas where the depth to groundwater is shallow, the $\delta^{18}O$ concentration is related to evaporation processes, and the values represent mixed groundwater (Africon, 2001). The δD results confirmed the evaporated nature of groundwater at the shallow wellpoints.

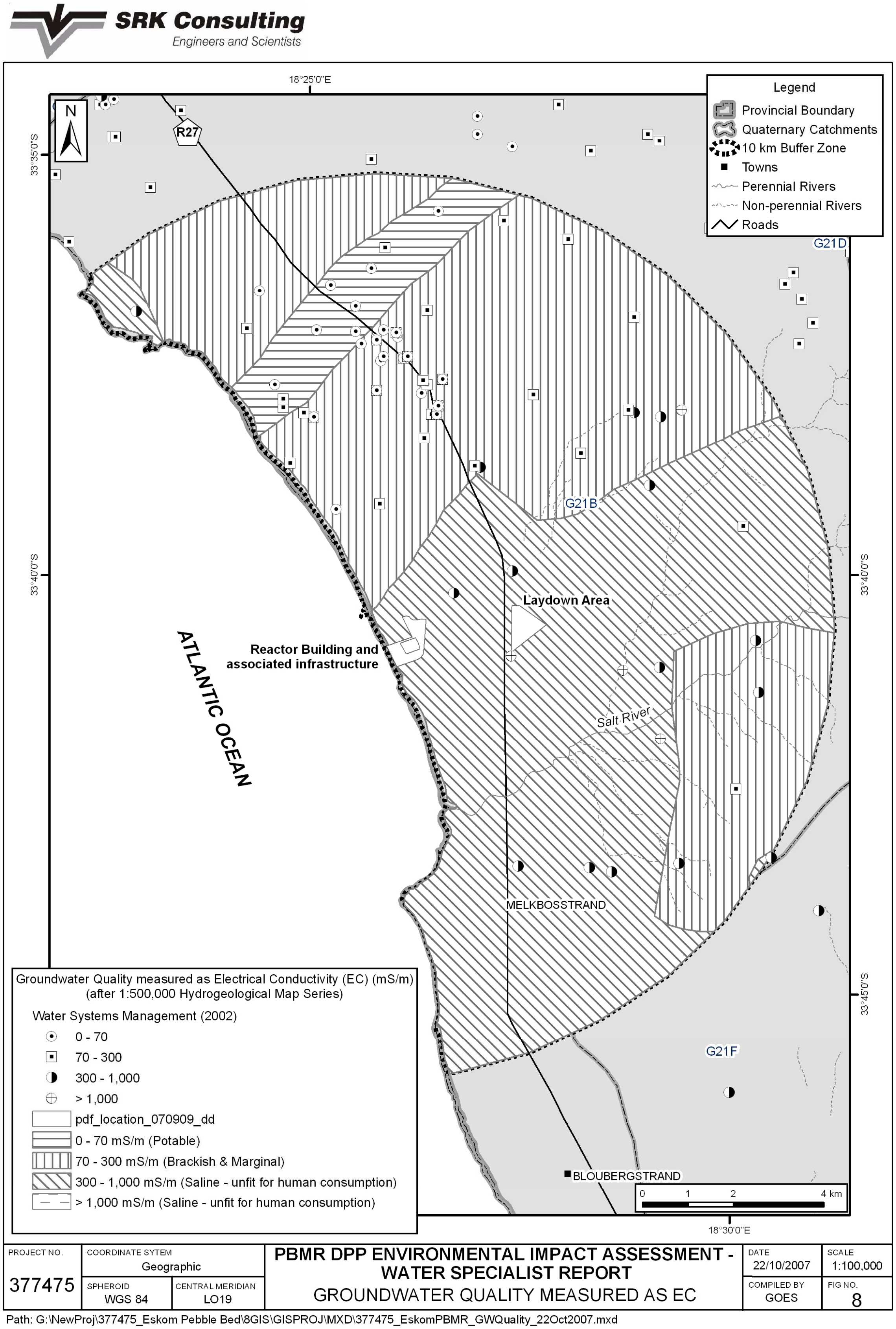

Figure 8: Groundwater Quality, as indicated by Electrical Conductivity (DWAF 1:500 000 Hydrogeological Map Series)

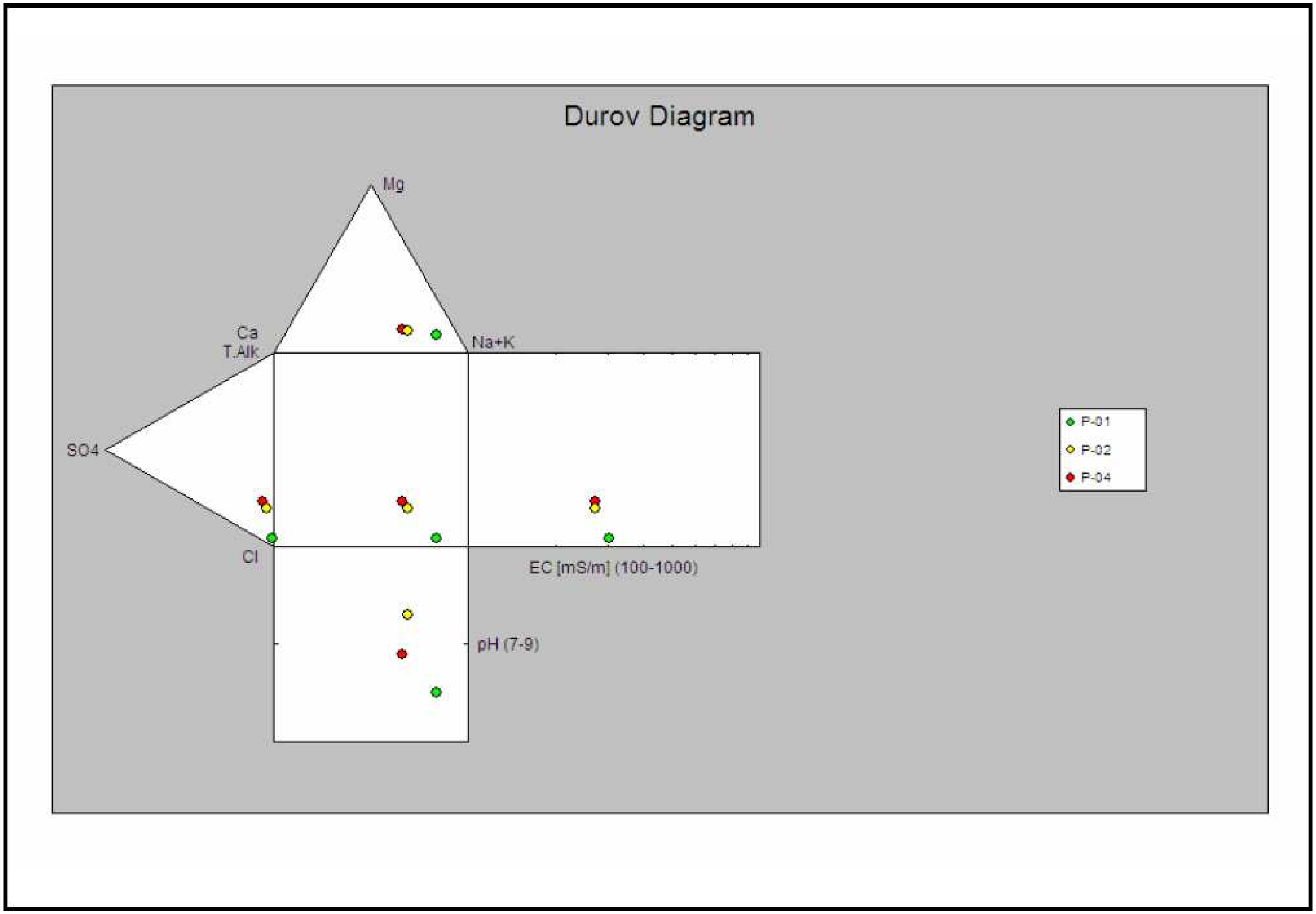

Figure 9: Hydrochemical Character of Groundwater

5.4.10 Groundwater Contamination

Groundwater quality monitoring results during 1977 and 1978 were assessed by Dames and Moore (1977a; 1977b; 1977d; 1978a and 1978b) and summarised by ESKOM (1997). It was apparent that dewatering processes during construction of the Koeberg 900 MW PWR Units 1 and 2 resulted in saline intrusion, evidenced by an increase in salinity in the groundwater at the monitoring boreholes.

Groundwater quality determined by Africon (2000) compared well with that during 1977, except for higher Cl and Na concentrations. This may be further evidence of saline intrusion that resulted due to the construction of Units 1 and 2. Sulphate (SO_4) concentrations also increased from 40 to > 400 mg/L subsequent to the dewatering phase (Dames and Moore, 1977d).

In regard to the risk of radioactive contamination of groundwater from existing nuclear islands, it is unlikely as the design and safety features of Units 1 and 2 will mitigate this. In the improbable event of a radioactive leakage from the nuclear island, the aseismic vault (i.e. built to withstand earthquakes) would prevent any contamination. Regular inspection of the aseismic vault is conducted to ensure that groundwater does not permeate through the retaining wall of aseismic vault (Eskom, 2006a).

Similarly, the waterproofing system applied to external walls below ground level at the Koeberg 165 MW PBMR Unit 3 will be designed to prevent the ingress of groundwater into the building as well as the egress of radioactive substances out of the building (Eskom, 2006a).

5.4.11 Potential Contamination Pathways

Local pathways for the migration of potential contaminants include the upper intergranular aquifer and the lower fractured rock aquifer. Contamination releases may migrate down-gradient through these aquifer systems. The extent of contamination would likely be restricted to within the Site footprint and coastal springs / seeps which may support sensitive ecosystems could be impacted on.

Leaks of any radioactivity will not directly affect existing groundwater users, but air emissions from the PBMR DPP could be transported inland by prevailing winds (regional pathway) and contaminate groundwater by being incorporated into rainfall recharge. Contamination by air emissions could extend for several kilometres depending on the climatic conditions at the time of the emissions. As a result, the extent of such contamination could cease further use of the regional Atlantis Aquifer.

5.4.12 Aquifer Classification and Vulnerability

The Atlantis Aquifer is classified as a Sole Source aquifer system (Parsons, 1995; Parsons and Conrad, 1998). Although smallholdings in the study area are dependent on groundwater, a reticulated pipeline was constructed during 2002. The primary aquifer system towards the eastern parts of the study area is therefore classified as a Major Aquifer system vulnerable to anthropogenic impacts (Parsons and Flanagan, 2006). The Malmesbury Group Aquifer is classified as a Minor Aquifer system, as this aquifer has low borehole yields, produces groundwater with variable quality and is of limited significance (Parsons, 1995; Parsons and Conrad, 1998). Minor aquifers have a moderate to low vulnerability to anthropogenic impacts.

6 Dewatering during Construction

Should construction of the PBMR DPP be approved, the planned area for such construction will require dewatering to a depth of 32 m below terrace level (mbtl) (Murray and Saayman, 2000). Groundwater levels in the primary aquifer are some 4 mbgl.

Saline intrusion will have to be considered during the design of a dewatering scheme at the Site. To ensure that the groundwater is not contaminated due to seawater ingress during dewatering, the groundwater levels at the Site will have to be maintained above sea level. A further concern is the potential for groundwater with poor quality from the Malmesbury Group to infiltrate into the primary aquifer, as the two aquifer systems are hydraulically connected.

Numerical Model by Murray and Saayman (2001)

A groundwater simulation model was used by Murray and Saayman (2001) to assist with the design of the dewatering system. This numerical model was divided into two 20 m thick layers to account for the primary aquifer and the underlying Malmesbury Group Aquifer. Four stages of wellpoints were used in the model. Wellpoints were ‘placed’ at 5 m intervals around the edge of the excavation, which was estimated to be 200 m by 150 m, in order to allow for an excavation slope of 0.5 (1:2). Seventeen deep boreholes were also included in order to dewater the secondary aquifer, and in order to assist in dewatering the sands above. Six of the 17 boreholes were located in the berm. This berm is the point where the flat excavated area (10 x 10 m) changes to a sloped surface that limits the movement of sand into the area excavated. The berm will not limit the movement of groundwater. The deep boreholes were assigned pumping rates of 2 to 5 L/s.

In all modelling runs, the wellpoints and deep boreholes proved effective in dewatering both the primary and secondary aquifers. Murray and Saayman (2001) thus recommended that wellpoints be used in conjunction with deep boreholes, and that a cut-off wall should not be used.

Murray and Saayman (2001) suggested that in order to prevent groundwater from flowing into the excavated areas, wellpoints should be installed around the edge of the excavated area. The unsaturated sand should be cleared away until the water table is reached (approximately 4 m). One deep borehole should be drilled at each corner of the excavation, and two deep boreholes along each length of the excavation (a total of 12 deep boreholes). Borehole P-01 should also be pumped at its maximum rate for the duration of the construction phase. Pumping of the wellpoints and the deep boreholes should commence ~ 15 days prior to excavation commencing (Murray and Saayman, 2001).

Murray and Saayman (2001) further recommended that to dewater the excavation a total of six to eight deep boreholes will have to be drilled. These boreholes should be designed to abstract groundwater from both the primary aquifer and the Malmesbury Group Aquifers, and should also prevent leakage from the underlying aquifer to the primary aquifer. Should fewer boreholes be drilled prior to commencing the dewatering phase, the excavation will have to be designed to allow for pumping from the open excavation. Sumps will have to be dug in the centre of the excavated area to allow for pumps to be installed there.

7 Potential Sources of Potable Water

7.1 Preamble

Previously, some 40 000 m^3/month (~ 15 L/s) of groundwater was abstracted from the 'Aquarius Wellfield' for potable use by Eskom at Koeberg. Due to elevated EC and Fe concentrations, the wellfield has not been used in the recent past for supplying the power station with a water supply.

The water consumption of the existing Koeberg 900 MW PWR Units 1 and 2 is measured at the meter chamber located to the east of the M14 at the power station boundary (Eskom, 2006b). Both of the existing Units 1 and 2 potable water system tanks have a capacity of 9 056 m^3, of which 1 730 m^3 is dedicated to the fire fighting water distribution system.

For the PBMR DPP, both helium and water will be required for cooling purposes. The water extracted from the sea will be used as a heat transfer medium to transfer heat from the helium. This is conducted in a closed circuit with no mixing of helium and water. Some 1.7 m^3/s (~ 53.6 Mm^3/a, based on a 24 hr/d over 365 d/a cycle) of cooling water will be discharged from the PBMR DPP back into the sea. The predicted cooling water volume is 34 times less than that for the existing Koeberg Nuclear Power Plant.

7.2 Groundwater Abstraction from the Primary Aquifer

The PBMR DPP is close to the coast and saline intrusion is a likely threat if the local primary aquifer is exploited. To ensure that seawater ingress does not occur, groundwater levels should be maintained above sea level during dewatering and any abstraction for use. This should be monitored. A further concern is the ingress of groundwater from the Malmesbury Group Aquifer. These aquifers are hydraulically connected. Pumping tests conducted in the primary aquifer showed a stabilisation of groundwater level drawdown above sea level when pumping individual boreholes at ~ 2.5 L/s (215 m^3/d) (Saayman and Weaver, 2001). A sustainable discharge maintaining groundwater levels above sea level would be within that range (Saayman and Weaver, 2001).

Saayman and Weaver (2001) suggested that previous investigations at the Site indicated that hydraulic conductivities in the area may be sufficiently high to allow for the installation of a collector well system. Such systems should reduce the potential for saline intrusion, as groundwater is 'skimmed' through the horizontal collectors resulting in minimal drawdown. Using Darcy's Law, Saayman and Weaver (2001) calculated that some 21.5 m^3/d of groundwater flows across the Site through the primary aquifer. This rate of flow was based on a natural hydraulic gradient, and should the collector system be actively pumped, the hydraulic gradient towards the collector system will become steeper and increase the available yield. They calculated that between 500 and 1 000 m^3/d could be sustainably abstracted using such a system.

Past experience in the vicinity of the Site has shown that these systems can be successful. Saayman and Weaver (2001) reported that three experimental systems installed at Silwerstroom Beach yielded 6.5 L/s each, i.e. ~ 540 m^3/d. At Blaawberg, their collector system sustainably supplies water for a golf course development. The hydrogeology at the Site is suitable for installing a collector system to about 14 m below the water table, i.e. approximately 21 mbgl.

7.3 Groundwater Abstraction from the Malmesbury Group Aquifer

Borehole P-01 was drilled into the Malmesbury Group Aquifer and yielded 12 L/s (1 040 m^3/d). A number of these boreholes could easily fulfil the water demand at the Site. Pumping tests were conducted on this borehole by Saayman and Weaver (2001). A drawdown of 28 m resulted in the groundwater level being some 20 m below sea level. Saline intrusion would therefore be likely should pumping at this rate continue. Malmesbury Group rocks are, however, known as poor water-bearing formations. A thorough groundwater development investigation including a geophysical survey would have to be undertaken to pinpoint geological fractures, which may enhance the water-bearing potential of the aquifer.

Murray and Saayman (2000) calculated that the specific capacity of the P-01 to be 0.36 L/s/m of drawdown. From this, it was calculated that to maintain the groundwater level above sea level, abstraction from the borehole should be ~ 2.7 L/s (233 m^3/d).

7.4 Surface Water Sources

Table 2 indicates high ‘Coefficient of Variation’ (CV) numbers, a clear indication that the watercourses in these catchments are generally non-perennial. This characteristic is logically related to rainfall patterns in the catchments. Surface water is therefore scarce in the region and does not form a viable or reliable source of potable water.

Surface water quality has not been investigated based on the fact that there is an insufficient potable surface water source in the region.

8 Impact Assessment

8.1 Preamble

Eskom (2006a) identified three potential scenarios involving groundwater impacts, namely:

- Risk of contaminating the groundwater resources;
- Risk of flooding by groundwater; and
- Risk of material degradation by groundwater.

These three potential impacts, as well as other future impacts (both positive and / or negative) associated with the PBMR DPP, are assessed for each of the four project phases, i.e. construction, commissioning, operation and decommissioning in the following Sub-Sections.

Surface water impacts have largely been ignored in historical studies, but there are scenarios that could lead to surface water impacts, namely:

- Insufficient provision in design for on Site surface water management;
- Risks related to design engineers overlooking the need to marry water quality concerns with water runoff management by adopting an integrated stormwater management approach.

8.2 Impacts during Construction Phase

8.2.1 Groundwater Impacts

As the natural groundwater level at the Site is some 4 mbgl, flooding will occur immediately when excavations commence (Table 5). Flooding of the excavations has been assessed from a hydrogeological perspective and the impact on groundwater conditions that exist at the Site, and not based on the impact on actual construction works. To mitigate this, the construction area and subsequent excavated areas must be dewatered either by constructing a cut-off / diaphragm wall or installing a series of wellpoints and boreholes. Murray and Saayman (2001) showed that the use of the latter mitigatory action will be feasible. According to them, one deep borehole should be drilled at each corner of the excavation, and two deep boreholes along each length of the excavation (a total of 12 deep boreholes). Pumping of the wellpoints and the deep boreholes should commence ~ 15 days prior to excavation commencing.

Dewatering the construction areas will result in lowering of the water table. Potential impacts relating to the declining water table include the threat of saline intrusion, drying up of coastal springs and / or seeps, drying up of wetlands, and decreased yields of existing production boreholes / wellpoints in the vicinity of the PBMR DPP. The coastal springs, seeps and wetlands may sustain sensitive ecosystems. The survival of such ecosystems may be threatened due to dewatering activities. An assessment of impacts to these surface freshwater ecosystems have been carried out by The Freshwater Consulting Group (Day, 2007), and includes identification and mapping of the wetlands on Site, classification of the wetlands and an assessment of wetland sensitivity and importance.

Based on the preliminary work conducted as part of the previous EIA process, it was recommended that an extensive pre-construction and construction groundwater monitoring programme be implemented to monitor groundwater levels and quality of the underlying aquifer systems (Murray and Saayman, 2001; Africon, 2001). To mitigate the impacts during the construction phase, should the construction of the PBMR DPP be authorised, a groundwater monitoring programme is being initiated by SRK Consulting as part of a different project for Pebble Bed Modular Reactor (Pty) Ltd. It is intended to commence with the monitoring programme during December 2007 so that sufficient baseline groundwater level and quality data can be collected prior to construction. According to PBMR (2007b), the scope of work for the intended groundwater monitoring programme is as follows:

- Installation of six groundwater monitoring boreholes;
- Weekly measurement of groundwater levels at the boreholes during pre-construction and construction;

- Weekly groundwater sampling at the boreholes to measure electrical conductivity (EC in mS/m), pH, temperature (as °C) and total dissolved solids (TDS in mg/L);
- Monthly groundwater sampling at the boreholes to analyse for potassium (K in mg/L), sodium (Na in mg/L), calcium (Ca in mg/L), magnesium (Mg in mg/L), sulphate (SO_4 in mg/L), chloride (Cl in mg/L), total alkalinity (T.Alk in mg/L) and tritium [^3H in Tritium Units (TU)];
- Annual rainwater sampling to analyse for the environmental isotopes deuterium (δD) and oxygen-18 (δ18O);
- Monthly interpretation of chemical analyses and the provision of recommendations to limit the impact on the environment;
- Monthly reporting of all interpreted monitoring data;
- Quality audit of sampling, chemical analyses and reporting; and
- Maintenance of the monitoring boreholes for the period pre-construction, during construction and commissioning up to the handover of the PBMR DPP to the Client.

Tritium monitoring will be implemented to monitor the potential ‘mixing’ of groundwater from the two aquifer systems, as well as the potential contamination from nuclear sources. Africon (2001) indicated that the primary aquifer displays a rain water tritium signal whereas the secondary aquifer contains a zero tritium signal. Mixed groundwater will fall in between these values, depending on the degree of mixing.

Contamination of the soil and groundwater by accidental spills of fuel, oil and / or grease must be kept to a minimum by applying a good ‘housekeeping’ approach. In the event of any such spillages, procedures must be in place to quickly and effectively repair any leakages and remove the contaminated soil. This soil must be collected and disposed of at a suitably licensed waste disposal facility.

Fuel, oil and / or grease should be stored on paved areas surrounded by oil catches, i.e. a sump surrounding the storage area to ‘catch’ all spilled fuel, oil and / or grease. This should be cleaned / removed regularly and disposed of at a suitably licensed waste disposal facility.

Contamination of the soil and groundwater by leaks and spillages from on-Site sanitation facilities must be kept to a minimum by conducting regular checks and repairs of any such leaks and spillages.

Should the results of groundwater monitoring indicate that contamination has occurred, remedial procedures will be put in place with immediate effect. A standard mitigation protocol cannot be currently presented, as the nature and extent of contamination would have to be firstly understood and addressed. Once contamination has been detected (predominantly based on a deterioration of groundwater quality), a site assessment would have to be undertaken. This assessment will include identifying the source of contamination and the scale of the problem. The extent of contamination could be investigated by augering a series of shallow, temporary exploration holes and collecting samples for analysis.

Once these tasks have been undertaken, the problem will be dealt with accordingly. Minor, insignificant levels of contamination may be mitigated with natural attenuation. Should the extent of contamination prove significant, the source of contamination will be removed and / or repaired, therefore preventing further contamination from occurring. By doing this, only existing contamination within the system will be dealt with. All contaminated soil and groundwater will be disposed of according to environmentally acceptable procedures, with full cooperation with the relevant authorities and full documentation on the quantities and methods of disposal.

Table 5: Groundwater Impacts during Construction Phase

Impact	Nature	Intensity	Extent	Duration	Probability	Confidence	Consequence	Significance
Impact 1: Flooding of the excavated areas by groundwater	Negative	Medium	Local	Short-term	Definite	High	LOW	LOW
With Mitigation	Neutral	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 2: Lowering of the water table due to dewatering and pumping of groundwater for construction use	Negative	Medium	Local	Short-term	Definite	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Definite	High	LOW	LOW
Impact 3: Intrusion of saline water due to dewatering and pumping of groundwater for construction use	Negative	Medium	Local	Medium term	Highly probable	High	MEDIUM	MEDIUM
With Mitigation	Negative	Low	Local	Short-term	Probable	High	LOW	LOW
Impact 4: Drying up of coastal springs and / or seeps due to dewatering and pumping of groundwater for construction use	Negative	Medium	Local	Medium term	Probable	Medium	MEDIUM	MEDIUM
With Mitigation	Negative	Low	Local	Short-term	Improbable	Medium	LOW	LOW
Impact 5: Drying up of wetlands due to dewatering and pumping of groundwater for construction use	Negative	Medium	Local	Medium term	Probable	Medium	MEDIUM	MEDIUM
With Mitigation	Negative	Low	Local	Short-term	Improbable	Medium	LOW	LOW
Impact 6: Decreased yields of existing production boreholes due to dewatering and pumping of groundwater for construction use	Neutral	Low	Local	Short-term	Improbable	High	LOW	LOW

Impact	Nature	Intensity	Extent	Duration	Probability	Confidence	Consequence	Significance
With Mitigation	Neutral	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 7: Organic and bacterial contamination of groundwater due to on-Site sanitation facilities' leaks and spillages	Negative	Low	Local	Short-term	Probable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 8: Hydrocarbon contamination of groundwater due to fuel, oil and grease storage facilities' leaks and spillages	Negative	Low	Local	Short-term	Probable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW

8.2.2 Surface Water Impacts

The area is characterised by minor drainage paths over a flat, sandy terrain with primary drainage paths (the Salt River in particular) located some distance from the Site. Normal impacts associated with surface water such as high consequence flooding linked to major watercourses are therefore absent from this project. Potential impacts are more closely linked to local stormwater management and management of contaminated rainwater runoff (Table 6).

During construction, extensive earthworks will be undertaken both at the laydown site and at the Nuclear Reactor site. It has been mentioned that the Sites have flat gradients and it is logical that these flat gradients will define low surface water flow velocities, reducing potential erosion risks. However, surface soils are non-cohesive and erosion related to rain events will be a concern. It is likely that such erosion may not produce significant scars (gulleys, etc) in surface soils, but the normal functioning of stormwater management infrastructure (surface drains, pipes etc) could be severely impeded by siltation resulting from surface soil erosion. This impact will be a cumulative impact, exacerbated with time. Mitigation will require strict control of site runoff during construction. This will require specifications documented in an Environmental Management Plan (EMP) to control runoff during construction.

Transport of contaminants via surface water during construction will be a risk and is thus identified as a potential impact. The primary source of contamination will be in maintenance of construction equipment where mechanical workshops and refuelling points will play a significant role. Primary containment of surface water runoff in these areas is critical as is the need for separating hydrocarbon contaminants (oil, fuel etc) from stormwater runoff. This is easily achievable with standard oil / water separator systems and sound equipment maintenance programs and will be the logical mitigation measure to employ.

Table 6: Surface Water Impacts during Construction Phase

Impact	Nature	Intensity	Extent	Duration	Probability	Confidence	Consequence	Significance
Impact 1: Erosion of surface soils	Negative	High	Local	Short-term	Highly probable	High	LOW	LOW
With Mitigation	Neutral	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 2: Contamination of surface water runoff	Negative	High	Local	Short-term	Highly probable	High	LOW	LOW
With Mitigation	Neutral	Low	Local	Short-term	Improbable	High	LOW	LOW

8.3 Impacts during Commissioning Phase

8.3.1 Groundwater Impacts

Other than the potential impacts associated with continuous groundwater abstraction for use during commissioning, other impacts during this phase may result from (Table 7):

- Nuclear fuel being transferred to the Site;
- Nuclear fuel loading at the Site; and
- Initial criticality and power ascension.

Flooding of the reactor has been assessed from a hydrogeological perspective and the impact on groundwater conditions that exist at the Site, and not based on the impact on the actual constructed works.

In regard to the degradation of the lower raft and retaining walls concrete, as well as soil cement sub-foundation by groundwater, the impact was assessed on the basis of the effect on groundwater quality, and not the effect on the actual structures.

As the commissioning phase represents the 'start-up' of the PBMR DPP, unknown problems with the construction of the system will be evident during this phase. Radioactive contamination with high intensity is more likely to occur during this phase. However, as continuous monitoring and performance evaluation during this phase will be carried out, the duration of potential impacts will be short.

The mitigatory actions remain the same as for that of the construction phase. In regard to the risk of radioactive contamination of groundwater from existing nuclear islands, it is unlikely as the design and all safety features of Units 1 and 2 will mitigate this. In the improbable event of a radioactive leakage from the nuclear island, the aseismic vault (i.e. built to withstand earthquakes) would prevent any contamination.

Table 7: Groundwater Impacts during Commissioning Phase

Impact	Nature	Intensity	Extent	Duration	Probability	Confidence	Consequence	Significance
Impact 1: Radioactive and toxic contamination of groundwater due to uranium and helium leaks and spillages	Negative	High	Local	Short-term	Improbable	Medium	MEDIUM	MEDIUM
With Mitigation	Negative	Low	Local	Short-term	Improbable	Medium	LOW	LOW
Impact 2: Flooding of the reactor by groundwater inflows	Negative	Medium	Local	Short-term	Probable	High	MEDIUM	MEDIUM
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 3: Degradation of the lower raft and retaining walls concrete, as well as cement sub-foundation by groundwater	Negative	Low	Local	Short-term	Probable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 4: Organic and bacterial contamination of groundwater due to on-Site sanitation facilities' leaks and spillages	Negative	Low	Local	Short-term	Probable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 5: Hydrocarbon contamination of groundwater due to fuel, oil and grease storage facilities' leaks and spillages	Negative	Low	Local	Short-term	Probable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 6: Lowering of the water table due to pumping of groundwater for use	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 7: Intrusion of saline water due to pumping of groundwater for use	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 8: Drying up of coastal springs and / or seeps due to pumping of groundwater for use	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 9: Drying up of wetlands due to pumping of groundwater for use	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW

Impact	Nature	Intensity	Extent	Duration	Probability	Confidence	Consequence	Significance
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 10: Decreased yields of existing production boreholes due to pumping of groundwater for use	Neutral	Low	Local	Short-term	Improbable	High	LOW	LOW
With Mitigation	Neutral	Low	Local	Short-term	Improbable	High	LOW	LOW

8.3.2 Surface Water Impacts

At the outset in the commissioning phase, it is possible that the newly constructed Sites will be characterised with extensive dust/silt build up emanating from recently completed construction activities. Surface water management systems could be adversely affected by siltation and a consequence of this could be localised flooding (e.g. at blocked stormwater nodes). Although flooding under these conditions is likely to be localised, safety may be affected in these localised areas. The extent of impacts on safety will be governed by the location of blockages (and localised flooding) should they occur. For example, should localised flooding occur at an electrical substation, this may result in localised power outages and could have knock on effects that impact on safe commissioning (Table 8). To mitigate against these risks, the commissioning phase should have a comprehensive operational plan that emphasises maintenance of all civils infrastructure (including surface water management features).

It is noted that the area has several seasonal wetlands that are primarily fed by groundwater. The seasonal nature of these wetlands appears to reflect on the rising groundwater table during the rainy season. It would, however, be short sighted to substantiate that the seasonality of these wetlands is not linked to surface water recharge. It is recognised that surface water recharge would probably play a lesser part in recharge of these systems, but removal of this source of recharge could have serious impacts on these wetlands. Diversion of Site stormwater into stormwater management infrastructure will largely cut off the supply of surface water to wetlands. The impacts related to this vary as follows:

- Impacts are positive should surface runoff be contaminated and directed away from wetlands and;
- Impacts are negative should a vital (seasonal) supply of water be removed from the wetlands by isolating local wetland catchments.

Should primary containment of contaminants be implemented, which is standard practice, it is then likely that little contaminated surface water runoff from the site will result and the primary impact of concern would be the potential reduction of surface water supply to the wetlands. To mitigate against this impact, it will be necessary to, within the Sites, allow natural flow of surface water into wetlands by bunding off (confining) plant areas from those areas locally draining into wetlands. This is a simple earthworks exercise.

Table 8: Surface Water Impacts during Commissioning Phase

Impact	Nature	Intensity	Extent	Duration	Probability	Confidence	Consequence	Significance
Impact 1: Localised flooding due to siltation of surface water management systems	Negative	High	Local	Short-term	Probable	Medium	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 2: Removal of surface water recharge from wetland systems	Negative	High	Local	Long-term	Probable	Medium	HIGH	HIGH
With Mitigation	Negative	Low	Local	Long-term	Improbable	High	LOW	LOW

8.4 Impacts during Operational Phase

8.4.1 Groundwater Impacts

The potential impacts during the operational phase remain the same as those during the commissioning phase. Three scenarios were considered / assessed, namely (a) operation under normal conditions, (b) operation including non-nuclear accidents, and (c) operation including a nuclear accident (Table 9). The type of radioactivity impacts without mitigation for either the non-nuclear or nuclear accident remains the same, except that the concentrations intensify significantly during nuclear accidents. Further, leaks of any radioactivity will not directly affect existing groundwater users, but air emissions from the PBMR DPP could be transported inland by prevailing winds and contaminate groundwater by being incorporated into rainfall recharge.

The potential impacts during the scenarios remain the same, other than the radioactive and toxic contamination of groundwater due to uranium and helium leaks and spillages during nuclear accidents. The latter is indicated in brackets in Table 9.

It has been shown that groundwater flows in a south-westerly direction towards the ocean. For this reason, any contaminated groundwater will discharge to the sea and could potentially be toxic to marine life. Although any contaminants may be concentrated in a small area, flow will be limited to a small area as well and the contaminants will dissipate. This potential impact on marine life must be assessed as part of a marine ecological specialist study, as the groundwater specialists do not have the expertise to properly assess such impacts.

The mitigatory actions remain the same as those for both the construction and commissioning phases.

Table 9: Impacts during Operational Phase (considering normal operation, non-nuclear accidents and nuclear accidents)

Impact	Nature	Intensity	Extent	Duration	Probability	Confidence	Consequence	Significance
Impact 1: Radioactive and toxic contamination of groundwater due to uranium and helium leaks and spillages	Negative	High	Regional	Short-term (Medium term)	Improbable (Probable)	Medium	MEDIUM (HIGH)	MEDIUM (HIGH)
With Mitigation	Negative	Low	Local	Short-term	Improbable	Medium	LOW	LOW
Impact 2: Flooding of the reactor by groundwater inflows	Negative	Medium	Local	Short-term	Probable	High	MEDIUM	MEDIUM
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 3: Degradation of the lower raft and retaining walls concrete, as well as soil cement sub-foundation by groundwater	Negative	Low	Local	Short-term	Probable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 4: Organic and bacterial contamination of groundwater due to on-Site sanitation facilities' leaks and spillages	Negative	Low	Local	Short-term	Probable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 5: Hydrocarbon contamination of groundwater due to fuel, oil and grease storage facilities' leaks and spillages	Negative	Low	Local	Short-term	Probable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 6: Lowering of the water table due to pumping of groundwater for use	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 7: Intrusion of saline water due to pumping of groundwater for use	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 8: Drying up of coastal springs and / or seeps due to pumping of groundwater for use	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 9: Drying up of wetlands due to pumping of groundwater for use	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 10: Decreased yields of existing	Neutral	Low	Local	Short-term	Improbable	High	LOW	LOW

Impact	Nature	Intensity	Extent	Duration	Probability	Confidence	Consequence	Significance
production boreholes due to pumping of groundwater for use								
With Mitigation	Neutral	Low	Local	Short-term	Improbable	High	LOW	LOW

8.4.2 Surface Water Impacts

During daily plant operation, impacts relating to poor management of surface water infrastructure are likely to be a recurring problem in the absence of sound management systems. The impacts are therefore the same as those during commissioning (Table 8).

8.5 Impacts during Decommissioning Phase

8.5.1 Groundwater Impacts

The potential impacts during the decommissioning phase remain the same as those during the operational phase (Table 10). However, the risk of radioactive and toxic contamination of groundwater will intensify during the decommissioning phase as a result of transfer of these substances off the Site.

Table 10: Impacts during Decommissioning Phase

Impact	Nature	Intensity	Extent	Duration	Probability	Confidence	Consequence	Significance
Impact 1: Radioactive and toxic contamination of groundwater due to uranium and helium leaks and spillages	Negative	High	Regional	Medium term	Improbable	Medium	MEDIUM	MEDIUM
With Mitigation	Negative	Low	Local	Short-term	Improbable	Medium	LOW	LOW
Impact 2: Flooding of the reactor by groundwater inflows	Negative	Medium	Local	Short-term	Probable	High	MEDIUM	MEDIUM
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 3: Degradation of the lower raft and retaining walls concrete, as well as soil cement sub-foundation by groundwater	Negative	Low	Local	Short-term	Probable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 4: Organic and bacterial contamination of groundwater due to on-Site sanitation facilities' leaks and spillages	Negative	Low	Local	Short-term	Probable	High	LOW	LOW

Impact	Nature	Intensity	Extent	Duration	Probability	Confidence	Consequence	Significance
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW
Impact 5: Hydrocarbon contamination of groundwater due to fuel, oil and grease storage facilities' leaks and spillages	Negative	Low	Local	Short-term	Probable	High	LOW	LOW
With Mitigation	Negative	Low	Local	Short-term	Improbable	High	LOW	LOW

8.5.2 Surface Water Impacts

Impacts during decommissioning will depend on the extent of the decommissioning exercise. Should the decommissioning philosophy be to return the Sites to their natural state, surface water impacts will be widespread as extensive landscaping will be required to:

- Return the Sites to their natural topography;
- Reduce surface accumulation in areas previously free draining;
- Promote surface water accumulation in natural wetland systems;
- Remove any potential for contamination, siltation and/or inundation of natural systems; and
- Reduce erosion risks.

Should the decommissioning philosophy be to make use of the Site infrastructure to the benefit of the community, impacts will remain similar to those in commissioning and operational phases with a strong emphasis on maintaining surface water management systems.

8.6 No-Go Alternative

8.6.1 Groundwater Impacts

Should the PBMR DPP not be constructed, the potential impacts identified previously, namely contamination of groundwater resources, flooding by groundwater and material degradation by groundwater will be avoided. However, the no-go alternative does not imply that the potential for a nuclear impact on groundwater may not occur. The PBMR DPP Site is situated on an existing nuclear power station property and directly adjacent to the nuclear reactors at Koeberg. For this reason, even without the PBMR DPP, there remains the potential for nuclear-related impacts.

8.6.2 Surface Water Impacts

Since potential surface water impacts are linked to local stormwater management and management of contaminated rainwater runoff, the no-go alternative will result in no impacts to surface water as there will be no construction, commissioning, operational or decommissioning phase to the project.

9 Conclusions

In light of the information and data presented in this report, the following conclusions are made:

9.1 Groundwater

- The Site is situated at the Koeberg Nuclear Power Station along the West Coast, approximately 30 km north of Cape Town CBD.

- The Site is located some 4.5 km south of the Atlantis Water Resource Management Scheme that includes the Witzand and Silwerstroom Wellfields, Infiltration Ponds 7 and 12, and the Coastal Infiltration Ponds.

- The Site overlies two aquifer systems, namely the southern extent of the upper primary or intergranular Atlantis Aquifer and the under-lying weathered and fractured-rock (secondary) aquifer system of the Malmesbury Group.

- The thickness of the primary aquifer at the Site is ~ 13 m, as the rest groundwater level is some 7 mbgl and the overall thickness of the sediments is ~ 20 m.

- Monitoring of groundwater levels indicates that levels at the Site vary between 3.4 and 4.3 mbgl. These shallow levels are the result of the groundwater at the Site being at the end of its flow path with the Site being very close to the coastline, i.e. located in a groundwater discharge zone.

- Groundwater flows in a south-westerly direction towards the coast. Abstraction from production boreholes in the 'Aquarius Aquifer', even at high abstraction rates, will not impact on the Site.

- Groundwater at the Site has a Na-Cl character, which is typical of groundwater in coastal zones. EC levels at the Site range between 270 and 305 mS/m, which is classified as marginal for drinking purposes and represents slightly saline conditions. The quality of the groundwater is a direct result of the closeness of these aquifers to the ocean.

- Atlantis is largely dependent on groundwater for its water supply. Some 8.5 Mm^3/a of groundwater is abstracted from the primary aquifer systems (Witzand and Silwerstroom Wellfields). Groundwater is also used in the study area as a source of water to smallholdings and for brick making and sand mining. As the Site is located directly adjacent to the ocean, there is no groundwater use down-gradient of the Site.

- Groundwater impact assessment matrices that have been prepared, show that the potential impacts at the Site are generally of low to medium consequence and thus has low to medium significance. The overall impact rating for groundwater is summarised in Table 11.

Table 11: Summary of overall rating for groundwater impacts

Criteria	Rating	
	Site-Specific	Off-Site (Air Emissions)
Extent or spatial influence of impact	LOW	REGIONAL
Intensity or magnitude of impact	LOW	HIGH
Duration of impact	SHORT-TERM to MEDIUM-TERM	LONG-TERM
Confidence	HIGH	HIGH
The activity will lead to an impact that is in all practical terms permanent	NO	YES

The groundwater specialist study confirms that there is no reason, from a groundwater perspective, why the planned PBMR DPP development at the existing Koeberg Nuclear Power Station should not be authorised. There are no fatal flaws in respect to the Site groundwater dynamics, conditions and use.

9.2 Surface Water

- No river channels drain the immediate Site. However, the perennial Salt and Diep Rivers drain the broader areas within the study area (10 km radius around the Site). The Donkergat River is a tributary of the Salt River.
- Surface water impacts of the proposed project are largely related to the way in which local stormwater is managed;
- An integrated approach to stormwater management is encouraged, ensuring that water quality and quantity aspects are taken into account in the detailed design of stormwater management systems.
- Surface water impact assessment matrices, show the potential impacts related primarily to integrated management of surface water to generally be of low consequence with the exception of impacts related to removing surface feeder water sources from wetlands, which carries a high consequence. Correspondingly, the significance ratings are generally low except for the wetland feeder cutoff impact, which is high. For all impacts, generally accepted best management practices can be employed as mitigation measures and should the mitigation measures suggested be implemented, all consequences (and corresponding significance rating) are reduced to low.

10 Recommendations

10.1 Groundwater

The objective of implementing mitigation measures and adhering to recommendations is to reduce potential impacts through the plant life cycle (construction to commissioning, to operation and ultimately decommissioning) of the planned expansion. Based on this, it is accepted that appropriate mitigation practises will form part of the design and planning through all phases of the proposed expansion project. The following measures should be implemented in order to reduce the significance rating of the potential impacts:

- To mitigate potential impacts during the various phases, a groundwater monitoring programme must be implemented. This is currently being initiated by SRK Consulting as part of a different project for Pebble Bed Modular Reactor (Pty) Ltd. It is intended to commence with the monitoring programme during December 2007 so that sufficient baseline groundwater level and quality data can be collected prior to construction.

- Contamination of the soil and groundwater by accidental spills of fuel, oil and / or grease must be kept to a minimum by applying a good 'housekeeping' approach. In the event of any such spillages, procedures must be in place to quickly and effectively repair any leakages and remove the contaminated soil. This soil must be collected and disposed of at a suitably licensed waste disposal facility.

Continuation of the groundwater monitoring programme is essential, as it will provide:

- Information on groundwater quality down-gradient of specific source areas in order to obtain time series groundwater quality data of the selected constituents, to verify selection of management actions and to determine the effectiveness of those actions;

- A reference database from which remediation programmes can be developed, if required; and

- A legally defensible database against which any possible future claims against Eskom Holdings regarding environmental contamination or human health risk can be measured.

10.2 Surface Water

Implementation of the mitigation measures suggested above is standard procedure and forms an integral part of best management practice in stormwater management design. It is recommended that all of these mitigation measures be implemented.

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